Utah State University

DigitalCommons@USU

Reports | Utah Water Research Laboratory

January 1986

Water Quality Management Studies for Water Resources Development in the Bear River Basin

Darwin L. Sorensen

Craig Caupp

William J. Grenney

Steve Eberl

Jay J. Messer

Phillip Ludvigsen

See next page for additional authors

Follow this and additional works at: https://digitalcommons.usu.edu/water_rep

Part of the Civil and Environmental Engineering Commons, and the Water Resource Management Commons

Recommended Citation

Sorensen, Darwin L.; Caupp, Craig; Grenney, William J.; Eberl, Steve; Messer, Jay J.; Ludvigsen, Phillip; and Ariss, Charles W., "Water Quality Management Studies for Water Resources Development in the Bear River Basin" (1986). *Reports.* Paper 73.
https://digitalcommons.usu.edu/water_rep/73

This Report is brought to you for free and open access by the Utah Water Research Laboratory at DigitalCommons@USU. It has been accepted for inclusion in Reports by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.

UtahStateUniversity
MERRILL-CAZIER LIBRARY

Authors
Darwin L. Sorensen, Craig Caupp, William J. Grenney, Steve Eberl, Jay J. Messer, Phillip Ludvigsen, and Charles W. Ariss

This report is available at DigitalCommons@USU: https://digitalcommons.usu.edu/water_rep/73

Water Quality Management Studies For Water Resources Development In The Bear River Basin

Final Report

Darwin L. Sorensen
Craig Caupp
William J. Grenney
Steve Eberl
Jay J. Messer
Phillip Ludvigsen
and
Charles W. Ariss

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

January 1986

99997

WATER QUALITY MANAGEMENT STUDIES
FOR WATER RESOURCES DEVELOPMENT IN THE
BEAR RIVER BASIN

Final Report

Darwin L. Sorensen
Craig Caupp
William J. Grenney
Steve Eberl
Jay J. Messer
Phillip Ludvigsen
Charles W. Ariss

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

January 1986

WATER QUALITY MANAGEMENT STUDIES

FOR WATER RESOURCES DEVELOPMENT IN THE

BEAR RIVER BASIN

Final Report

Darwin L. Sorensen
Craig Caupp
William J. Grenney
Steve Eberl
Jay J. Messer
Phillip Ludvigsen
Charles W. Ariss

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

January 1986

ACKNOWLEDGMENTS

The work reported herein was funded by the State of Utah, Department of Natural Resources, Division of Water Resources. We gratefully acknowledge the project direction of Craig Miller of the Division of Water Resources and the helpful input of Gene Bigler, Norm Stauffer, and Lloyd Austin.

The participation of the Utah State Department of Health, Department of Environmental Health, Bureau of Water Pollution Control in establishing new sample sites, collecting and analyzing river samples each month, and for helpful suggestions and enlightening discussions is also gratefully acknowledged. Richard Denton coordinated and made major contributions in these activities. Richard Bay of the Metropolitan Water District of Salt Lake City has actively participated in project progress reviews.

We appreciate the skilled technical assistance of Robert Dicksa and Jean Ihnat in the laboratory, and the computer wizardry of Charles Liff in manipulating data files, and generating graphics routines.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

SUMMARY

The quality of water that develops in the proposed reservoirs of the Upper Bear River Storage Project will determine the possible uses of the water.

Previous studies of water quality in the Bear River and its tributaries have reported water quality problems relating to nitrate ion, sanitary indicator bacteria, suspended solids, and phosphorus concentrations. Most point sources of water pollution in the basin have been eliminated or improved in quality, but nonpoint sources of pollution continue to degrade the quality of the Bear River. Concentrations of phosphorus have been sufficiently high to encourage dense algal growth and create eutrophic conditions in the proposed impoundments where other factors were not limiting. The present study intended to investigate these problems relative to the potential use of impounded water for municipal and industrial purposes.

Past water quality information for the study area of the Bear River basin was reviewed including analysis of 208 areawide planning data and STORET data accumulated by the Utah Bureau of Water Pollution Control since 1977. Salinity components were found to be the major factors describing water quality in the Bear River, but nutrients and microbial pollution indicators were also very important. Nitrate concentrations were not found to have approached the 10 mg $N \cdot \ell^{-1}$ standard in the historical data reviewed.

Thirteen monthly water quality sampling and analyses were performed from 15 locations on the Bear River and its tributaries beginning above Oneida Reservoir, Idaho, and extending to the interstate highway bridge near Honeyville, Utah. These data indicated that the Cub River continues to be an important source of nutrients and microbiological pollution to the Bear River. The lower reaches of the Little Bear River occasionally accumulated undesirable concentrations of biochemical oxygen demand, nutrients, and fecal indicator bacteria.

Increases in suspended solids and phosphorus loads in the Bear River and its tributaries were observed during spring snowmelt and runoff. Weston Creek, Fivemile Creek, and Deep Creek carried exceptionally high suspended solids and phosphorus loads during this time. A major increase in total phosphorus and orthophosphorus in the Bear River below the confluences of these streams was observed. Landsliding and erosion in the watersheds of these streams probably contribute substantially to their phosphorus and sediment loads.

A water temperature model, empirical trophic state models, and a computerized reservoir eutrophication model (RESEN) were used to simulate the eutrophication potential of the proposed reservoirs. Since turbidity is expected to decrease over the length of the reservoirs allowing more light energy for photosynthesis, and since ample phosphorus will be available, the proposed Amalga Reservoir is likely to be eutrophic near the dam and in the Cub River branch. Similarly, the proposed Honeyville Reservoir is likely to be eutrophic near the dam, and pools of anoxic water may develop below the thermocline. High populations of zooplankton could reduce summertime algal populations in the Honeyville

Reservoir of mesotrophic to eutrophic conditions. Zooplankton grazing has been observed to substantially reduce algal populations in the existing Hyrum Reservoir on the Little Bear River.

The proposed Lower Oneida Reservoir in Idaho will probably not thermally stratify, but will have a temperature regime similar to the existing Oneida Reservoir and remain essentially completely mixed throughout the year. The depth of mixing of the water column is expected to limit algal growth and maintain this reservoir in an oligotrophic condition.

The proposed Mill Creek and Avon Reservoirs on the Blacksmith Fork and Little Bear Rivers, respectively, will probably produce spring and fall algal blooms of mesotrophic to eutrophic proportions. Strong thermal stratification of these reservoirs in the late spring will isolate the epilimnion from phosphorus sources. Available phosphorus in the epilimnion will be exhausted through algal growth and settling, and phosphorus in the photic zone will not be replaced until destratification occurs in the fall.

Reservoirs may remove phosphorus from streams by trapping sediment and converting soluble phosphorus to algae or other plants that are retained in the reservoir. Lower phosphorus concentrations in the stream then result in less productive conditions in downstream reservoirs. The proposed upstream reservoirs on the Bear River or its tributaries are not expected to produce an appreciable improvement in downstream reservoirs, however. Phosphorus inputs from tributaries and nonpoint sources will probably negate phosphorus removal by these reservoirs.

A study of chemical use by the Little Cottonwood water treatment plant revealed a general independence on raw water quality except for taste and odor. Assuming that water from the Honeyville Reservoir will receive conventional treatment and treatment with permanganate to control taste and odor in the same way as water is treated at the Little Cottonwood plant, treatment costs were estimated to be approximately $80 per acre ft. If trihalomethane compounds are formed from chlorination of the water, and concentrations exceed drinking water standards, treatment costs would increase by $6 to $190 per acre ft depending on the degree of removal required and the treatment method selected. If eutrophic conditions can be prevented from developing in the Honeyville Reservoir, concentrations of trihalomethane precursors produced by algal growth and decomposition would be expected to be low, and trihalomethane formation would not be expected to be a problem.

INTRODUCTION

The ways in which the water resources developed in the Upper Bear River Storage Project may be economically used will be determined by the quality of the water stored in the reservoirs. Water treatment processes are capable of producing high quality water from raw water with low quality, but costs associated with treatment increase with decreasing raw water quality. Bear River water has been reported to contain concentrations of nitrate ion, sanitary indicator bacteria, and suspended solids that diminish its quality as a raw water source for municipal and industrial use. In addition, concentrations of phosphorus have been sufficiently high to promote concentrated algae growth in water impoundments that would result in eutrophic conditions. The present study was initiated to investigate the severity of these problems, and to develop procedures for modeling the eutrophication potential of the reservoirs proposed for the Bear River and its tributaries.

To accomplish these tasks a review of previous water quality studies on the Bear River was conducted, and water quality data resident in the U.S. Environmental Protection Agency's STORET data storage and retrieval system was analyzed. The number of sampling stations used by the Utah Bureau of Water-Pollution Control (BWPC) was increased to include locations representative of proposed reservoir sites, and intensive, localized water quality sampling and analysis studies were conducted by the Utah Water Research Laboratory. The existing Oneida and Cutler Reservoirs were studied to learn the physical and chemical behavior of Bear River reservoirs. Based on information gained through this work, the eutrophication potential of the proposed reservoirs was modeled using a water temperature model and a longitudinal finite-difference eutrophication simulation model. An empirical trophic state model for lakes and reservoirs was also applied.

PREVIOUS STUDIES OF BEAR RIVER WATER QUALITY

Surprisingly few Bear River water quality studies have been published. Table 1 lists the studies which have produced reports or compilations of data. All of these studies were conducted by the Utah Water Research Laboratory. The U.S. Geological Survey (USGS) and Utah Bureau of Water Pollution Control (BWPC) have entered their water quality monitoring data for the Bear River into the U.S. Environmental Protection Agency's (USEPA) STORET data storage and retrieval system since 1964. An analysis of BWPC STORET data collected from January 1977 through December 1983 is discussed below.

Hydrologic Inventory of the Bear River Study Unit

Maps depicting mean annual concentrations and loads of total dissolved solids (TDS) in the Bear River basin between the headwaters and Brigham City were prepared by Haws and Hughes (1973) from data collected in a cooperative study between USGS and the Utah Department of Natural Resources, Division of Water Resources (DWR), starting in 1967. These data indicated a relatively constant salinity between Oneida and Cutler Reservoirs, with higher salinity water from the Cub River and the Slough areas combining with lower salinity waters from the Logan and Little Bear Rivers to yield water of increased salinity (800-900 mg $TDS \cdot \ell^{-1}$) below Cutler Reservoir.

Planning for Water Quality in the Bear River System

In 1973 and 1974 the UWRL cooperated with BWPC in developing a water quality plan for the Bear River system in Utah. This work led to the development of a water quality management plan pursuant to the objectives of the Federal Water Pollution Control Act, including the 1972 amendments (section 303C). Sampling and analysis of water quality done during this study were added to STORET. The planning report addresses geology, surface and groundwater resources, and uses of water within the basin. General land use patterns in the Bear River basin are delineated and their potential impact on stream water quality discussed. Rangeland (44.7%), cropland (35.9%), and forested land (18.4%) constituted the major land use types within the basin. Four hundred fifty dairy and feedlot operations in the basin were mapped and tabulated according to the municipality in which they are located, and the problems associated with controlling nutrients and other pollutants from these operations were discussed. Water quality problems in the basin in 1974 were ranked in the following order: (1) sewage discharges, and (2) nutrients and salinity from agricultural activities, and mineral springs.

As part of this same effort, the impact of reducing or increasing sewage discharges on water quality in the Bear River system was analyzed using computer simulation techniques. The results of this "waste load allocation" process are resident with the BWPC. Considerable progress has been made since 1974 in controlling wastewater discharges from municipal and industrial facilities within the basin. However, the challenges of controlling nonpoint sources of water pollution in the basin still remain.

Table 1. Previous studies of Bear River basin water quality.

Title	Document Produced
Hydrologic Inventory of the Bear River Study Unit	Haws and Hughes (1973)
Planning for Water Quality in the Bear River System	UWRL (1974)
The Effects of Artificial Destratification on Water Quality and Microbial Populations in Hyrum Reservoir	Drury et al. (1975)
A Technique for Predicting the Aquatic Ecosystem Response to Weather Modification	Israelsen et al. (1975)
Water Quality Working Paper for Bear River Basin Cooperative (Type IV) Study, Idaho, Utah, Wyoming	UWRL (1976)
Naturally Occurring Organic Compounds in Eutrophic Hyrum Reservoir, Utah	Renk et al. (1978)
Bear River 208 Water Quality Data Summary	UWRL (1980)
Evaluation of Livestock Runoff as a Source of Water Pollution in Northern Utah	Wieneke et al. (1980)
Natural Salinity Removal Processes in Reservoirs	Messer et al. (1981)
Calcium Carbonate Precipitation as Influenced by Stream Primary Production	Rupp and Adams (1981)

Soil Conservation Service Cooperative Study

Under the sponsorship of the USDA Soil Conservation Service, the UWRL (1976) inventoried water quality throughout the Bear River basin using data from STORET and limited data collected as part of the study in Idaho and Wyoming where STORET data were not available. Data were compared with existing water quality standards established by the appropriate states and violations were tabulated. Trends in the data, modified by water use and management policy, were used to project water quality in the basin in 1985 and 2020. Impacts of then current and projected quality on various uses of Bear River water were discussed.

In Utah, violations of water quality standards for the Bear River in effect in 1975 (current standards are not appreciably different, Table 2) involved primarily total coliform bacteria ($\geq 5000 \cdot 100\ m\ell^{-1}$), and biochemical oxygen demand ($BOD_5 \geq 5\ mg \cdot \ell^{-1}$). Frequent problems relative to the recommended limit for TDS ($\geq 500\ mg \cdot \ell^{-1}$) were also noted. Violations of stream standards in samples collected

Table 2. Water quality standards for beneficial uses of the Bear River (classes 2B: boating, water skiing, not swimming; 3B: warm water aquatic life; 3D: waterfowl, 4: agricultural), Little Bear River (classes 3A: cold water aquatic life; 3D; 4), Logan River (classes 3A, 3D, and 4), Blacksmith Fork (classes 3A and 4), and the Cub River (classes 3B and 4) (Utah Department of Health 1978).

	CLASSES											
	Domestic Source			Recreation & Aesthetics		Aquatic Wildlife				Agri-culture	Indus-try	Special
Constitutent	1A	1B	1C	2A	2B	3A	3B	3C	3D	4	5	6
Bacteriological (No./100 ml)								STANDARDS WILL BE DETERMINED ON A CASE-BY-CASE BASIS (SEE APPENDIX D)			STANDARDS WILL BE DETERMINED ON A CASE-BY-CASE BASIS	STANDARDS WILL BE DETERMINED ON A CASE-BY-CASE BASIS
(30-day Geometric Mean)												
Maximum Total Coliforms	1	50	5,000	1,000	5,000	*	*		*	*		
Maximum Fecal Coliforms	*	*	2,000	200	2,000	*	*		*	*		
Physical												
Total Dissolved Gasses	*	*	*	*	*	(b)	(b)		*	*		
Minimum DO (mg/l) (a)	*	*	5.5	5.5	5.5	6.0	5.5		5.5	*		
Maximum Temperature	*	*	*	*	*	20°C	27°C		*	*		
Maximum Temp. Change	*	*	*	*	*	2°C	4°C		*	*		
pH	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	5.5-9.0	6.5-9.0		6.5-9.0	6.5-9.0		
Turbidity increase (c)	*	*	*	10 NTU	10 NTU	10 NTU	10 NTU		15 NTU	*		
Chemical (Maximum mg/l)												
Arsenic, dissolved	.05	.05	.05	*	*	*	*		*	.1		
Barium, dissolved	1	1	1	*	*	*	*		*	*		
Cadmium, dissolved	.010	.010	.010	*	*	.0004(d)	.004(d)		*	.01		
Chromium, dissolved	.05	.05	.05	*	*	.10	.10		.10	.10		
Copper, dissolved	*	*	*	*	*	.01	.01		*	.2		
Cyanide	*	*	*	*	*	.005	.005		*	*		
Iron, dissolved	*	*	*	*	*	1.0	1.0		1.0	*		
Lead, dissolved	.05	.05	.05	*	*	.05	.05		*	.1		
Mercury, total	.002	.002	.002	*	*	.00005	.00005		.00005	*		
Phenol	*	*	*	*	*	.01	.01		*	*		
Selenium, dissolved	.01	.01	.01	*	*	.05	.05		*	.05		
Silver, dissolved	.05	.05	.05	*	*	.01	.01		*	*		
Zinc, dissolved	*	*	*	*	*	.05	.05		*	*		
NH_3 as N (un-ionized)	*	*	*	*	*	.02	.02		*	*		
Chlorine	*	*	*	*	*	.002	.01		*	*		
Fluoride, dissolved (e)	1.4-2.4	1.4-2.4	1.4-2.4	*	*	*	*		*	*		
NO_3 as N	10	10	10									
Boron, dissolved	*	*	*	*	*	*	*		*	.75		
H_2S	*	*	*	*	*	.002	.002		*	*		
TDS (f)	*	*	*	*	*	*	*		*	1200		
Radiological (Maximum pCi/l)												
Gross Alpha	15	15	15	*	*	15(g)	15(g)		15(g)	15(g)		
Radium 226, 228 combined	5	5	5	*	*	*	*		*	*		
Strontium 90	8	8	8	*	*	*	*		*	*		
Tritium	20,000	20,000	20,000	*	*	*	*		*	*		
Pesticides (Maximum ug/l)												
Endrin	.2	.2	.2	*	*	.004	.004		.004	*		
Lindane	4	4	4	*	*	.01	.01		.01	*		
Methoxychlor	100	100	100	*	*	.03	.03		.03	*		
Toxaphene	5	5	5	*	*	.005	.005		.005	*		
2, 4-D	100	100	100	*	*	*	*		*	*		
2, 4, 5-TP	10	10	10	*	*	*	*		*	*		
Pollution Indicators (g)												
Gross Beta (pCi/l)	50	50	50	*	*	50	50		50	50		
BOD (mg/l)	*	*	5	5	5	5	5		5	5		
NO_3 as N (mg/l)				4	4	4	4		*	*		
PO_4 as P (mg/l)(h)	*	*	*	.05	.05	.05	.05		*	*		

* Insufficient evidence to warrant the establishment of numerical standard. Limits assigned on case-by-case basis.

(a) These limits are not applicable to lower water levels in deep impoundments.

(b) Not to exceed 110% of saturation.

(c) For Classes 2A, 2B, 3A, and 3B at background levels of 100 NTUs or greater, a 10% increase limit will be used instead of the numeric values listed. For Class 3D at background levels of 150 NTUs or greater, a 10% increase limit will be used instead of the numeric value listed. Short term variances may be considered on a case-by-case basis.

(d) Limit shall be increased threefold if $CaCO_3$ hardness in water exceeds 150 mg/l.

(e) Maximum concentration varies according to the daily maximum mean air temperature.

Temp. °C	mg/l
12.0 and below	2.4
12.1 to 14.6	2.2
14.7 to 17.6	2.0
17.7 to 21.4	1.8
21.5 to 26.2	1.6
26.3 to 32.5	1.4

(f) Total dissolved solids (TDS) limit may be adjusted on a case-by-case basis.

(g) Investigations should be conducted to develop more information where these pollution indicator levels are exceeded.

(h) PO_4 as P(mg/l) limit for lakes and reservoirs shall be .025.

from tributaries to the Bear River during this study were primarily due to total and fecal coliforms and involved the Cub River, Logan River, Little Bear River, Malad River, and Box Elder Creek in Utah.

Very few reliable trends in the water quality data for the Bear River were identified. Of interest in the present study was the decreasing trend in total coliform bacteria in the Bear River at Amalga (STORET No. 491433). The annual average through 1973 was 1.4×10^4 total coliforms per 100 ml, while the projected annual average for 1985 and 2020 was 1×10^3 per 100 ml. This decrease was probably due to the elimination of a sewage discharge from a local cheese factor in 1972.

The potential effects of such factors as water rights (effects on flow rates), irrigation return flows, fertilizer use, municipal and industrial discharges, and dairy and beef cattle feeding operations are discussed. Using computerized modeling techniques, it was estimated that 20 to 30 percent of the total salinity is added to the Bear River from agricultural sources each year.

Bear River 208 Water Quality Data Summary

Under contract with the Bear River Association of Governments (BRAG), the UWRL collected and analyzed samples from the Bear and Cub Rivers in Utah between 14 April and 9 October 1980 as part of an areawide waste treatment management planning effort (PL 92-500, Sec. 208). Twenty-three sites on the Bear River, two on the Cub River, and one on City Creek, a tributary to the Cub River, were sampled regularly. An additional fourteen Bear River and four Cub River sites were sampled occasionally to gain more information about possible problem areas. Regular samples were taken monthly, and additional samples taken after rainstorms. Sampling locations are shown in Figure 1.

Water quality measurements included field parameters (temperature, dissolved oxygen, and flow) and laboratory analyses of pH, ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), orthophosphate (PO_4-P), turbidity, conductance, suspended solids, total dissolved solids, biochemical oxygen demand (BOD_5), total coliforms, fecal coliforms, and fecal streptococci.

Class 2B (Table 2) water quality criteria were occasionally exceeded at the Cub River sites, and at Bear River sites below the Cub River confluence and upstream from the Benson Marina. Orthophosphate criteria were exceeded in 31 percent of the samples, total coliforms and fecal coliforms exceeded criteria in 21 and 19 percent of the samples, respectively. Eleven percent of the samples collected 14 April 1980 exceeded the 5 $mg \cdot \ell^{-1}$ BOD_5 standard. BOD_5 in all samples on subsequent sampling dates was below the standard.

To our knowledge the 208 plan for the Bear River area has not yet been completed and made available for public use.

Data from the 1980 208 field study were converted to electronic media to allow both graphical and multivariate statistical analyses to be applied to the data. Examples of graphical analyses are presented in Figures 2-10. In the first three figures, logarithms of the various microbial indicators are plotted as a function of distance, downstream from the Idaho border (river mile = 0). In the total coliform graph (Figure 2), it is apparent that these organisms were present at relatively low numbers below river mile 9 (above the Cub River). The numbers increased substantially immediately below the confluence of the Cub (miles 12 and 14), and reached relatively high levels near Amalga (mile 19), where they remained throughout the river reach above Cutler Reservoir. Fecal coliforms

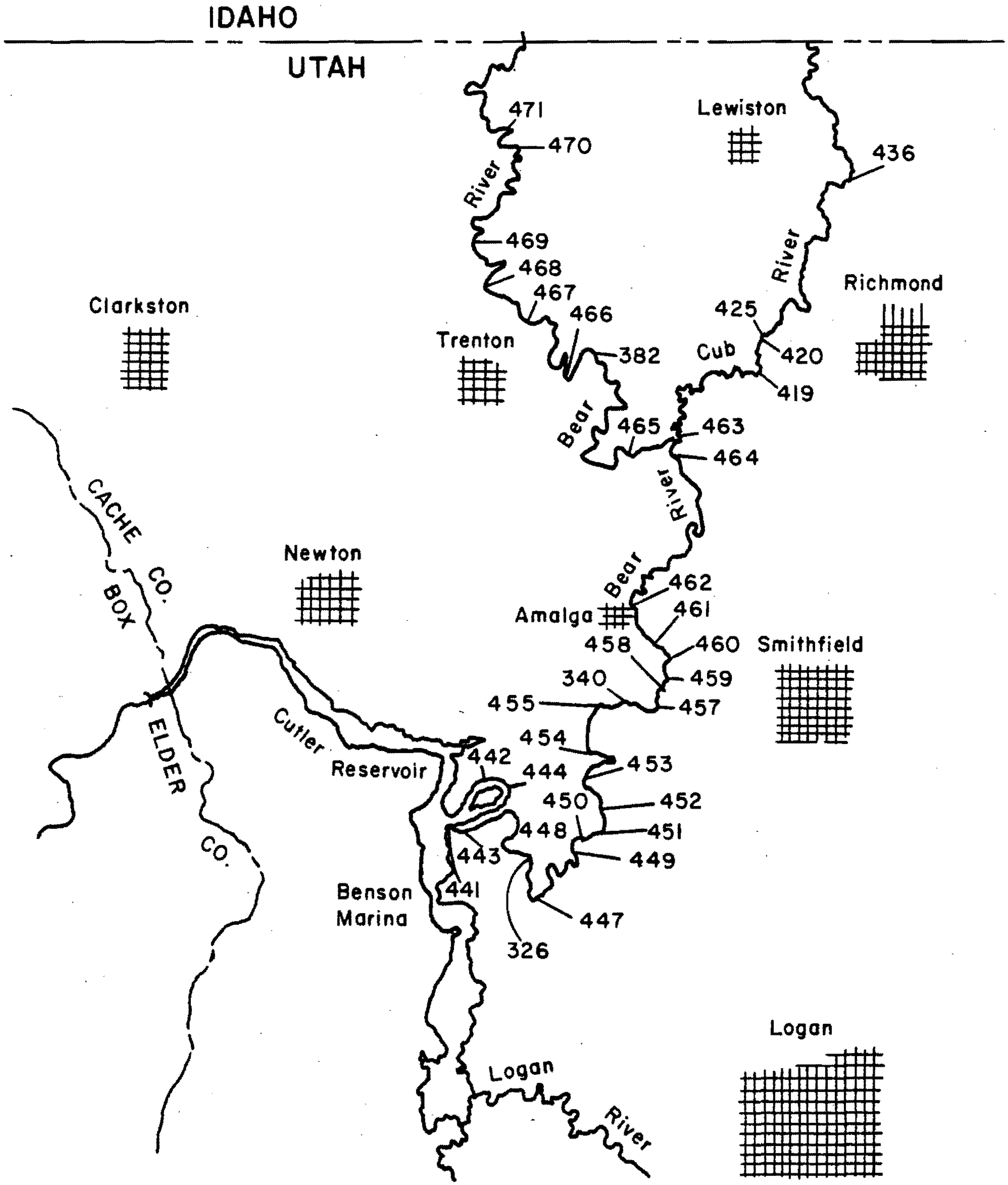


Figure 1. Location of sampling stations for the Bear River 208 planning study. All station numbers are STORET numbers and have the prefix 490.

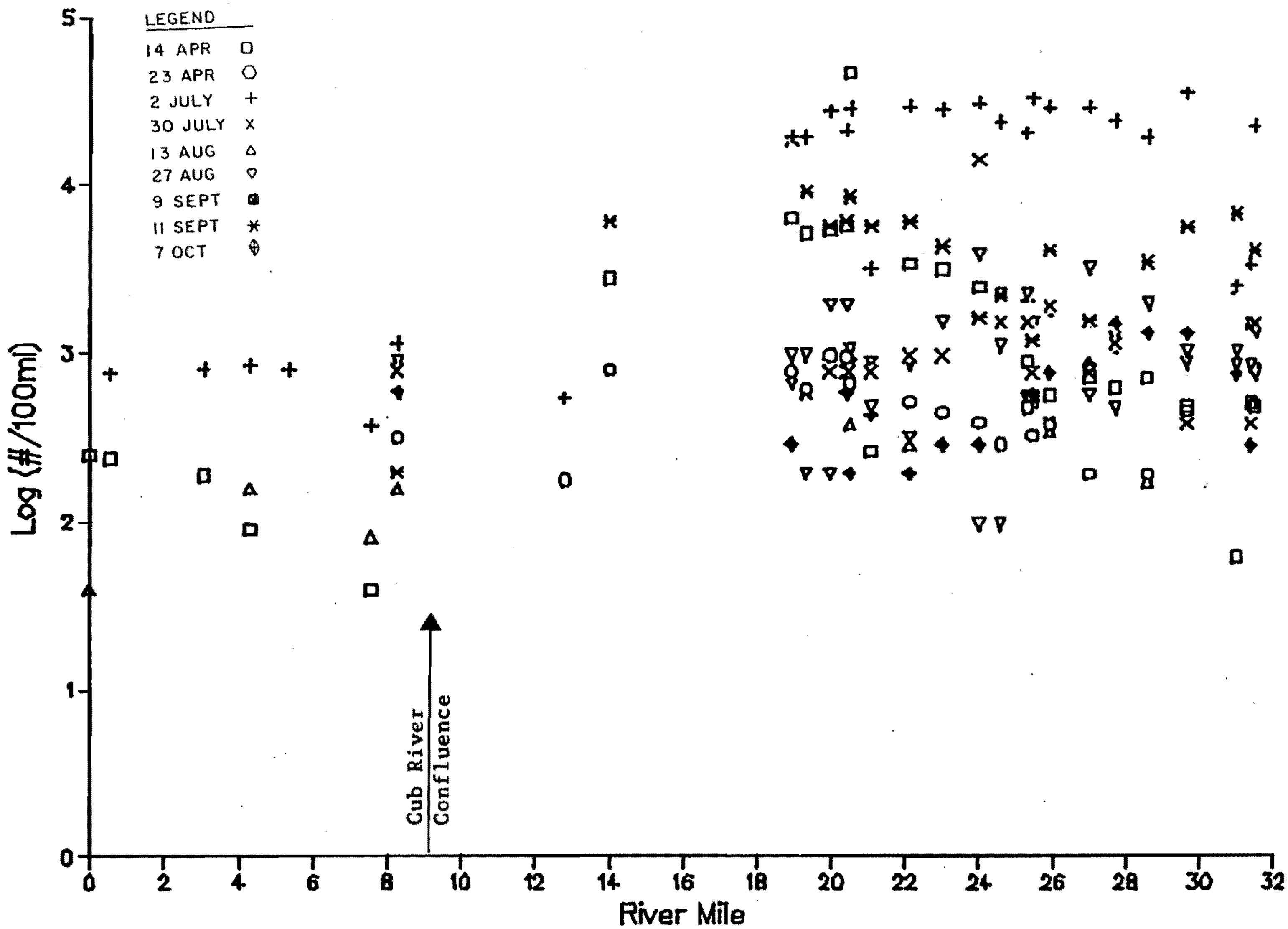


Figure 2. Total coliforms on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

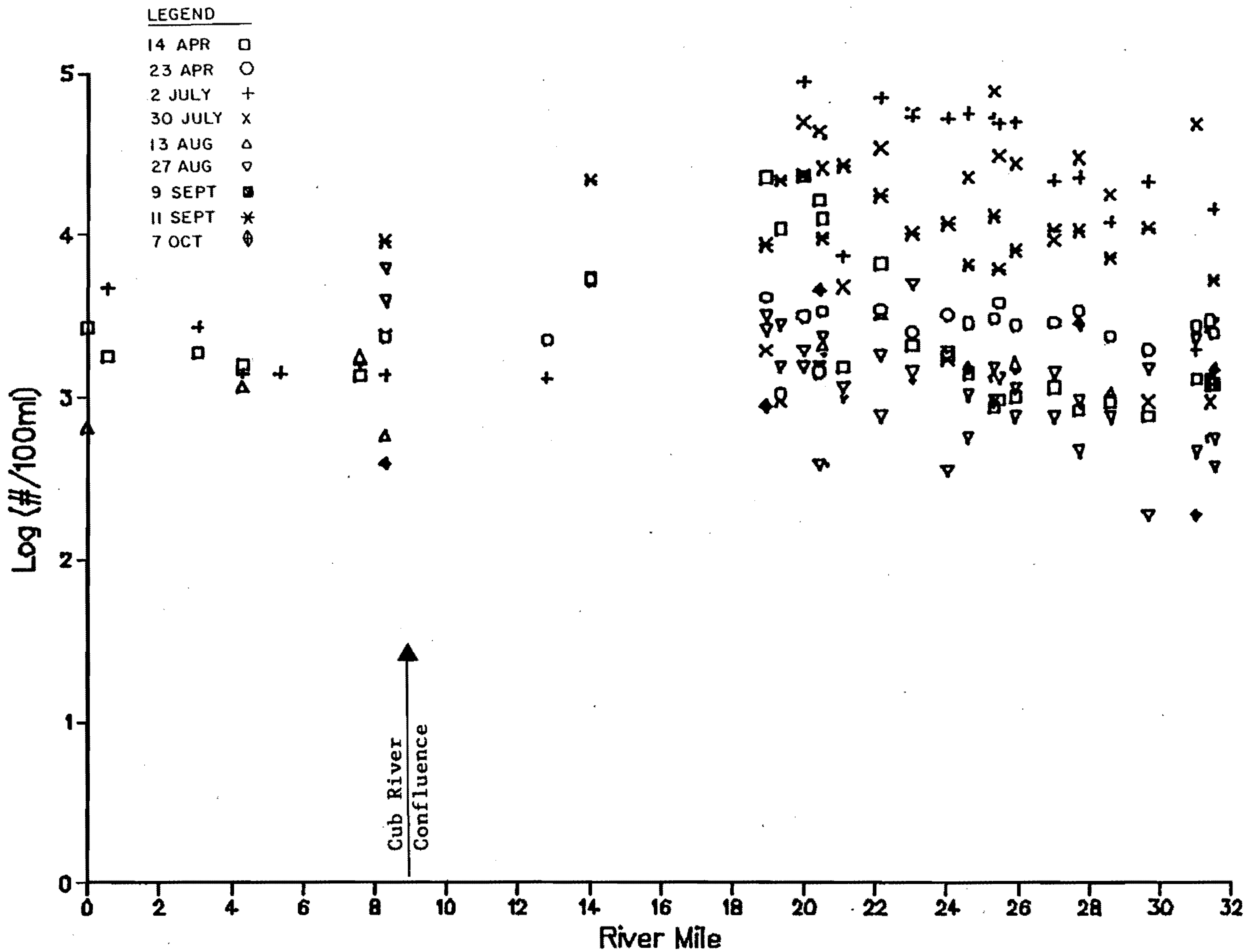


Figure 3. Fecal coliforms on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

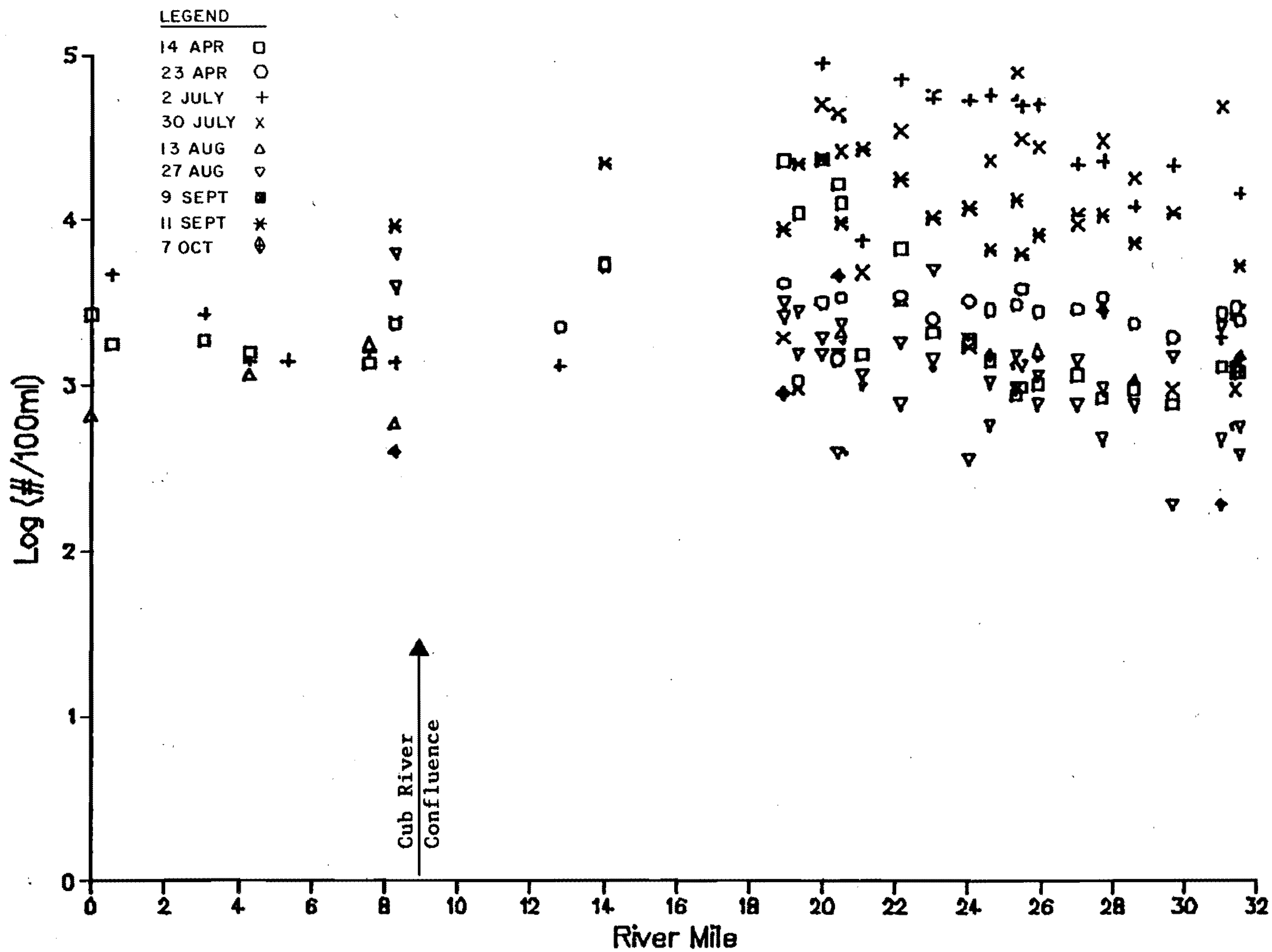


Figure 4. Fecal streptococci on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

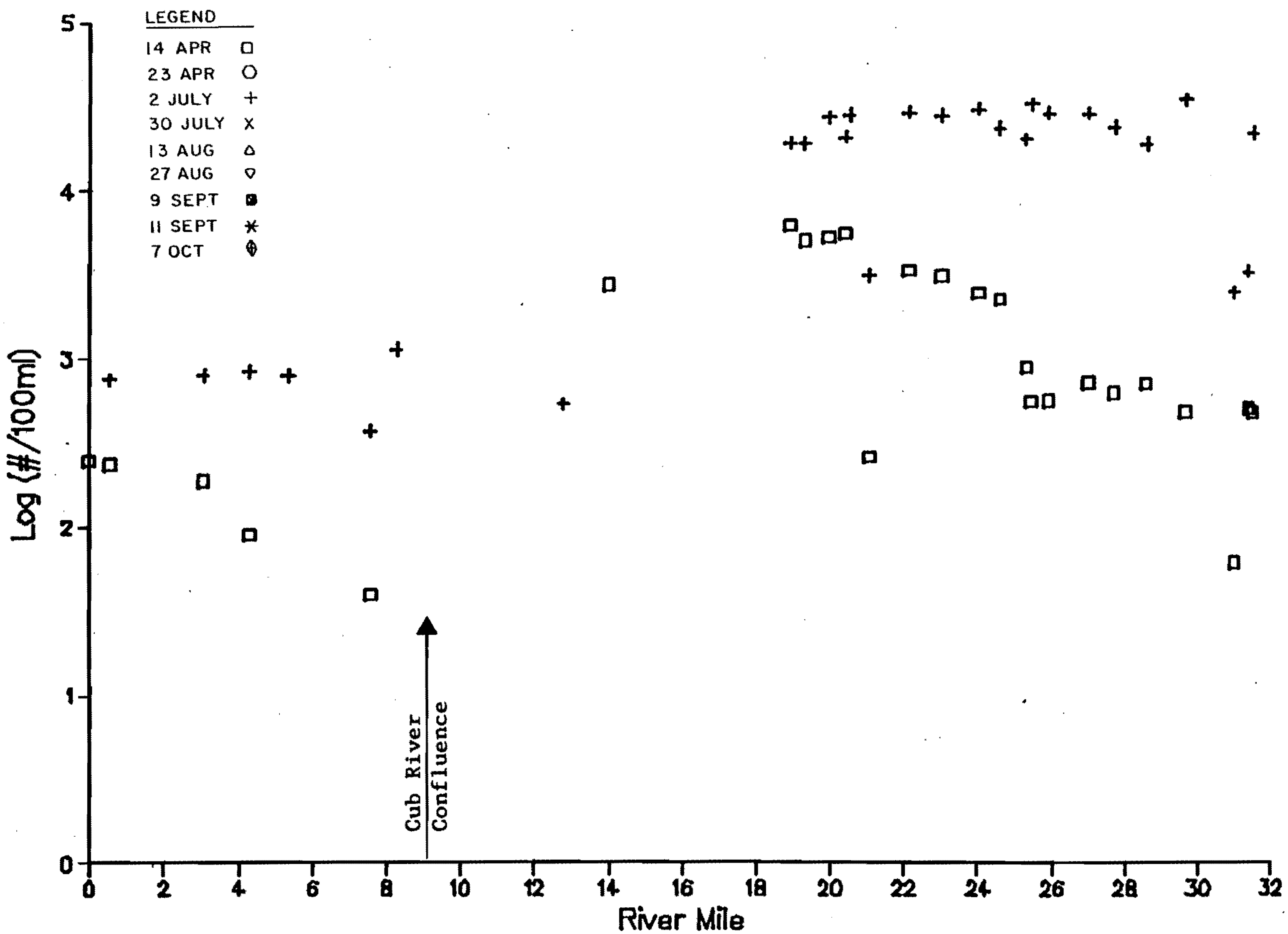


Figure 5. Total coliforms in the Bear River mainstem on April (□) and July (+) sampling dates. River mileage increases downstream from the Utah-Idaho border.

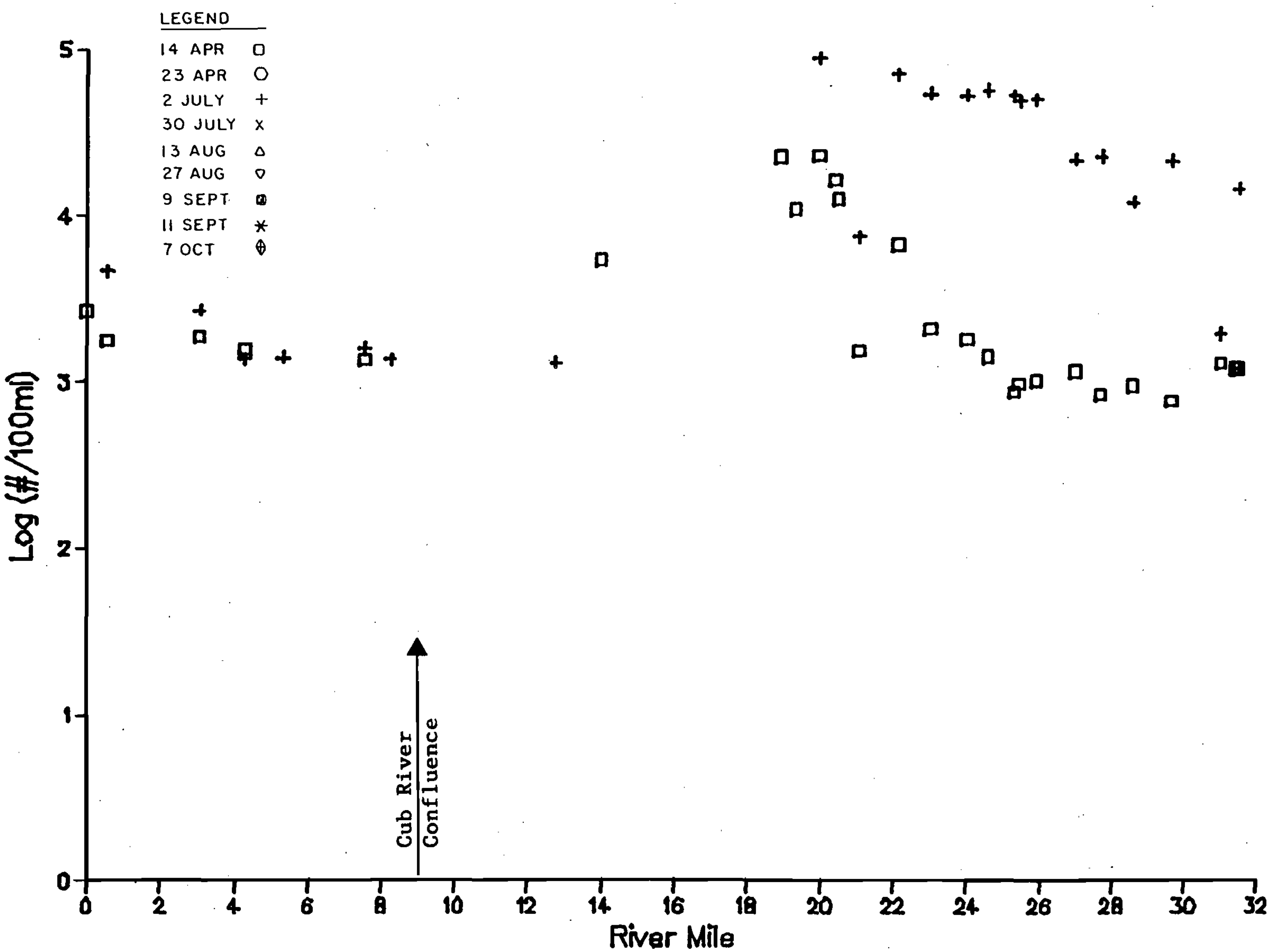


Figure 6. Fecal streptococci in the Bear River mainstem on April (□) and July (+) sampling dates. River mileage increases downstream from the Utah-Idaho border.

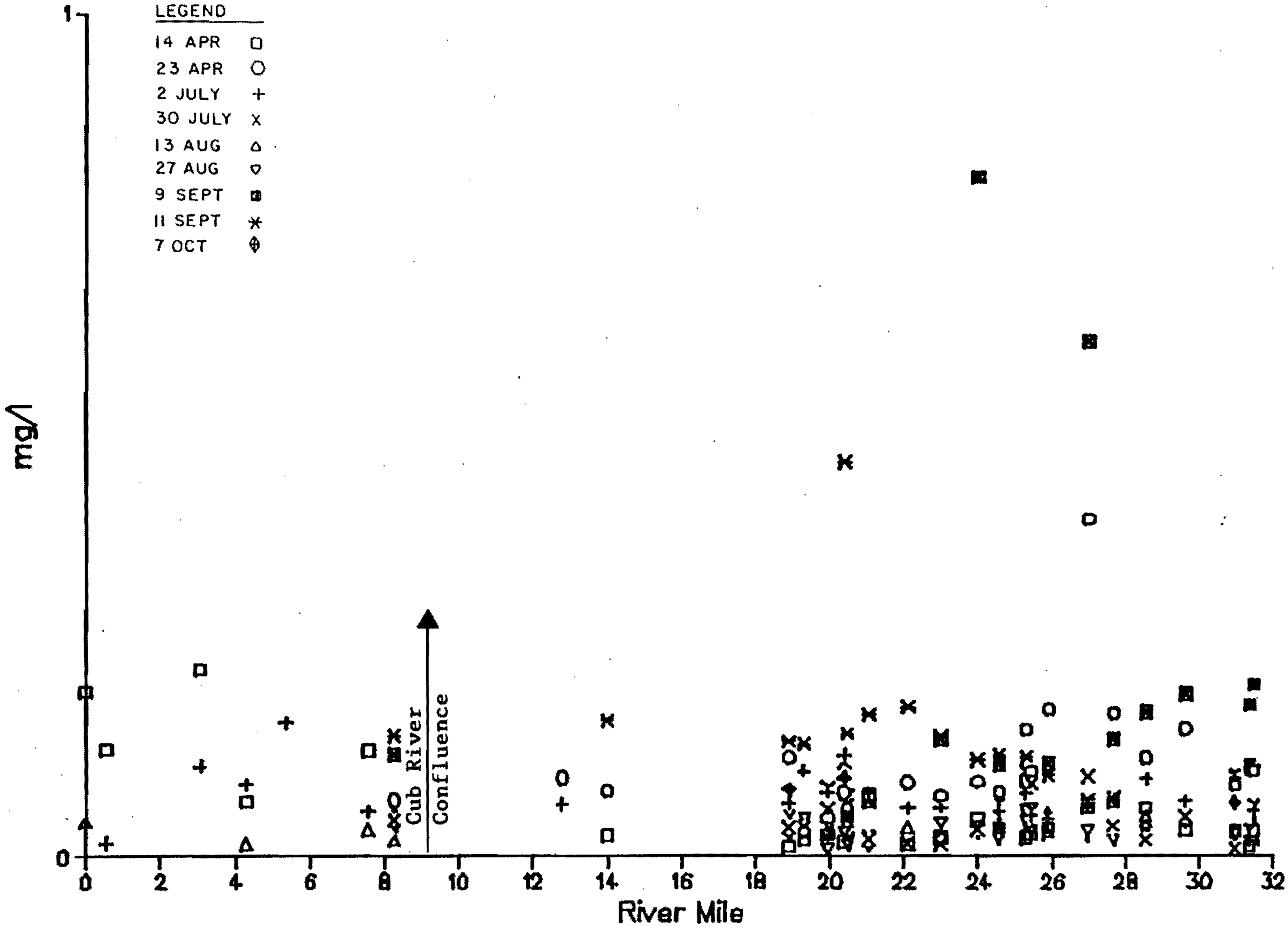


Figure 7. Ammonia-N on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

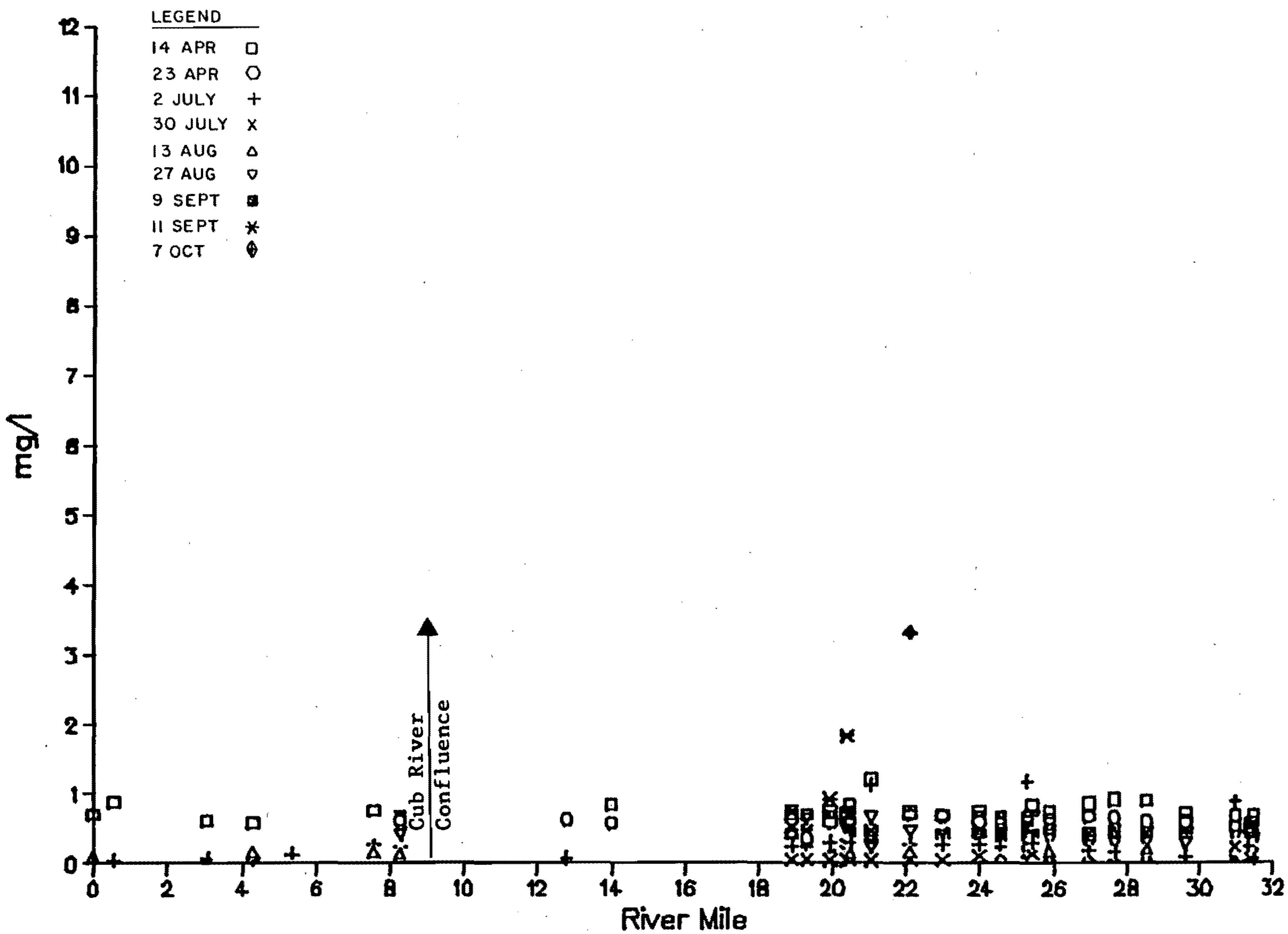


Figure 8. Nitrate-N on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

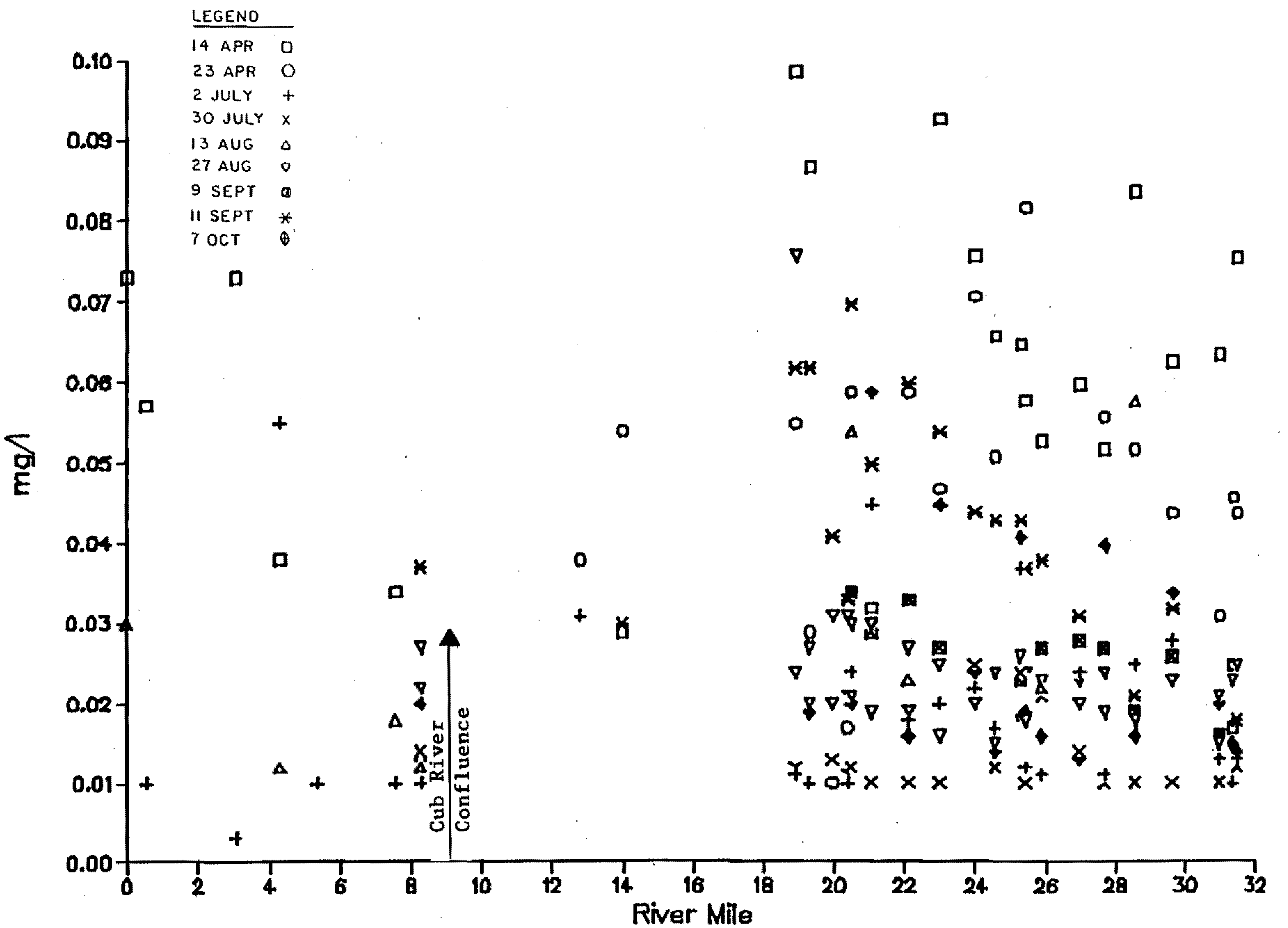


Figure 9. Orthophosphate on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

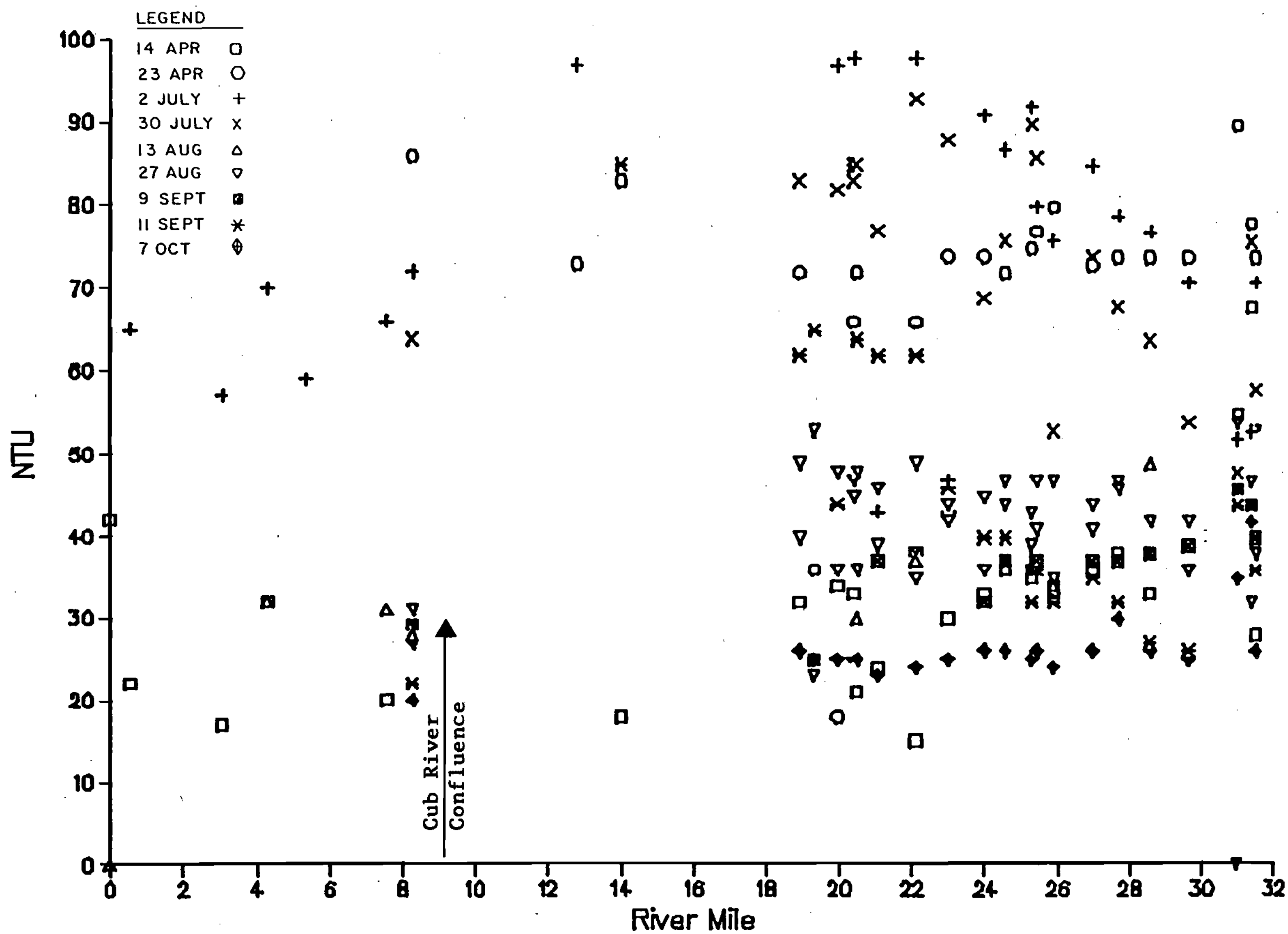


Figure 10. Turbidity on all sampling dates on Bear River mainstem. River mileage increases downstream from the Utah-Idaho border. Different symbols represent different sampling dates.

and fecal streptococci showed similar, but less distinct, trends when all of the data were examined (Figures 3 and 4). The fact that all sites were not sampled on every trip makes analyzing differences in mean data risky, if not actually misleading. However, if the data from two dates when most of the sites were sampled are compared (Figures 5 and 6), it is possible to get a synoptic picture of what was happening in the river. The data shown are from April 14, during spring runoff, and July 2, substantially after peak flows had occurred. On the April date, total coliforms declined from the Idaho line to the Trenton Bridge (mile 8) and increased substantially below the Cub River. Total coliforms peaked in the area of Amalga, and then declined substantially in a downstream direction. Fecal streptococci showed a similar pattern in April, although without the decline in the most upstream reaches of the study area. On the July date, patterns were similar, except that there was no increase in either microbial indicator below the Cub River. The increase in the vicinity of Amalga occurred again, but was not accompanied by the subsequent decrease downstream. These patterns are consistent with a strong local source of microbial contamination in the area of Amalga (probably animal feeding operations) in both spring and summer. During spring runoff, this contamination was diluted (or destroyed) in the downstream direction, while it was more conservative during summer flows. The Cub River apparently furnished an important microbial contaminant load only during high flows in the spring.

Analysis of the ammonia and nitrate data (Figures 7 and 8) indicated little upstream-downstream trends in the data, nor did "hot spots" stand out (other than occasional and isolated high values in the reach between Amalga and Cutler Reservoir). Orthophosphate concentrations (Figure 9) appeared to be generally low at the Trenton Bridge, and to substantially increase below the Cub and again in the vicinity of Amalga. Turbidity (Figure 10) generally increased below the confluence with the Cub River, where it reaches Cutler Reservoir. Taken together, these data indicate that orthophosphate, which may be kept in equilibrium with suspended particulates, generally tracks the microbial contaminants, being highest near Amalga. The nitrogen species, which may travel largely as groundwater recharge to the river, are more uniform throughout the reach.

Another way to examine the relationships among stations exhibiting suites of water quality data is cluster analysis. This technique first standardizes all water quality variables using a z-transformation, thus making all variables equal to each other according to their deviation from the mean value for the data set (as a percentage of the standard deviation). The mean euclidian distance of each variable from the corresponding variable for every other observation is then calculated, and a dissimilarity matrix is constructed. From this matrix, a cluster diagram (or "dendogram") is produced in which stations with similar water quality cluster more closely together than do dissimilar stations.

An example of this analysis technique is shown for all stations on April 23, 1980, in Figure 11. As an example of how this type of analysis is used, stations 490452 and 490453 are very similar in water chemistry, while station 490448 is extremely unlike any other station. Branch points nearest the left side of the dendogram enclose the most similar stations, and similarities decrease among the stations enclosed by branches toward the right of the dendrogram. Cluster analyses were performed for all sampling dates, and the farthest two and six outliers were identified for each date. The results of this analysis indicated that stations 490420, 490419, 490425, and 490463 were among the two farthest outliers at least three times on the various sampling

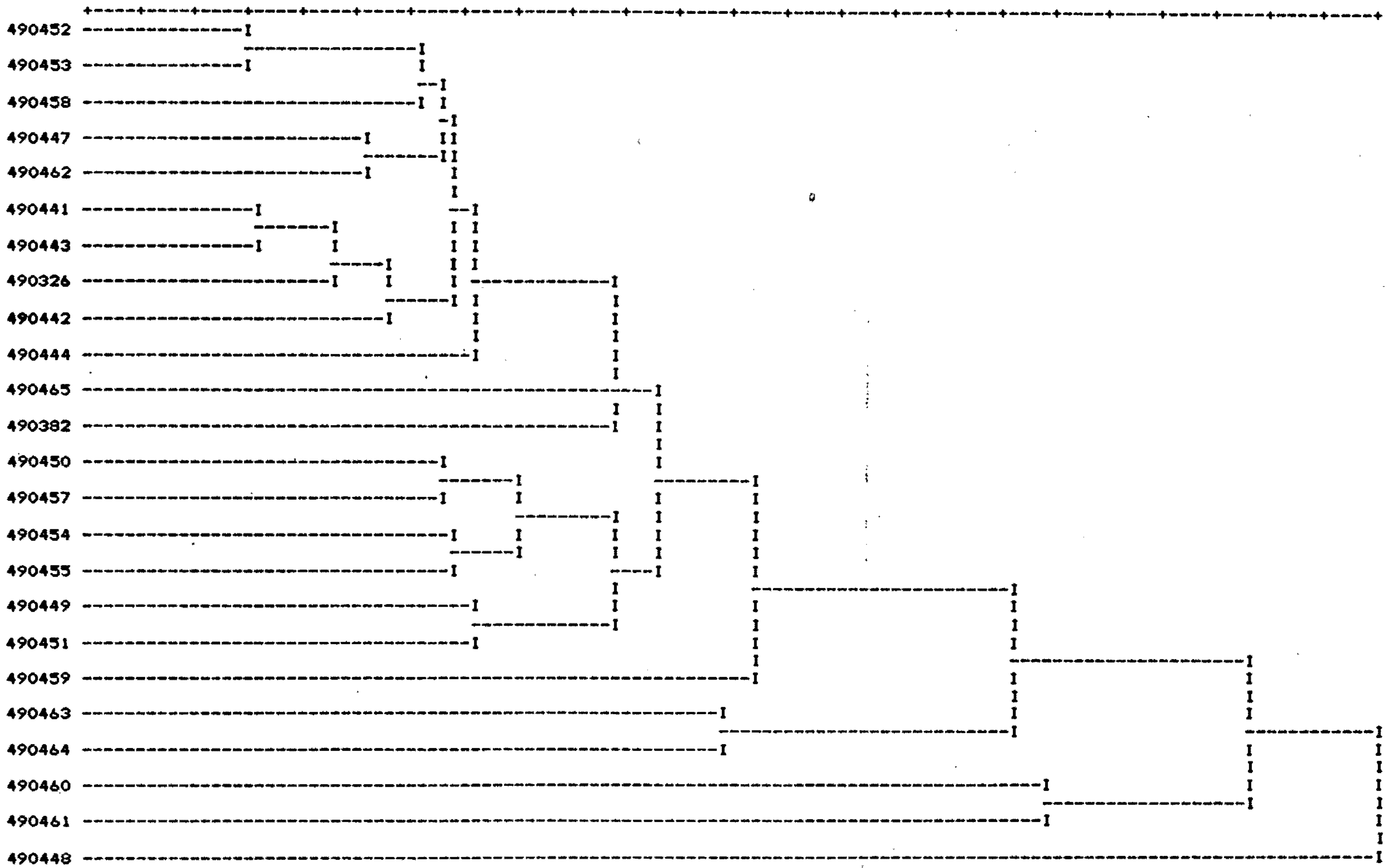


Figure 11. Cluster analysis of Bear River 1980 - 208 water quality data by station (shown as STORET numbers). Similar stations join the tree toward the left of the figure.

dates. Extension to six outliers added stations 490442 and 490443 to the list of unusual stations. These stations were all either on the Cub River below Richmond, where they were impacted by wastewater discharges, on the large oxbow on the Bear River immediately above Cutler Reservoir, or about 0.1 mile upstream from Cutler Reservoir. It is interesting that the lowermost station on the Bear River above Cutler Reservoir does not appear in the list. The reasons for the uniqueness of all of these stations cannot be determined using cluster analysis, but possible explanations could include either natural geochemical differences (including dissolved solids concentrations or sediment loads) or pollution sources. In any case, the Bear River stations below Amalga do not emerge as being especially unusual.

The above station cluster is often called a "Q-type" analysis. Alternatively, the same data can be clustered by attribute (in this case by water quality variables) in an "R-type" cluster. This analysis was performed for all stations on each date, and the results tabulated as above. In this case, the three water quality variables that clustered most uniquely were conductivity, turbidity, and suspended solids. We believe that this result indicates that most of the pollutant variables (e.g., nutrients and microbial contaminants) have a tendency to cooccur, and that they behave relatively independently of the major flow-related variables such as dissolved and suspended solids.

A more elegant way of examining relationships between water quality variables is principal components analysis. This multivariate statistical technique again searches for commonalities or differences in standardized data, and assigns the variability in a data set to a series of eigen vectors, each of which accounts for a certain degree of the variation in the total data set. Each eigenvector is associated more or less strongly, in a positive or negative way, with the various standardized water quality variables. Results of a principal components analysis of the Bear River data are shown in Table 3. The Cub River stations are analyzed separately, because the PCA showed that they were unlike the Bear River stations in their water chemistry. The two unusual Bear River (oxbow) stations also were excluded.

The PCA indicates that four eigenvectors account for 76.6 percent of the Bear River sample variability. The first factor accounts for 33.7 percent of the model variability, and is strongly loaded on nutrients and suspended sediments. The strong negative loading on temperature indicates that these contaminants are usually associated with colder water, probably spring runoff. The second factor, which accounts for 20 percent of the model variability, is a microbial factor, and indicates that the microbial indicators travel together, and largely exclusive of the other parameters. Factor 3 is a turbidity and conductivity factor, and factor 4 is associated with nitrogen pollutants.

The data in Table 3 can be compared with the results of the Cub River PCA in Table 4. In the Cub, two eigenvalues accounted for virtually 100 percent of the model variability. These included a strong factor associated with turbid water rich in ammonia-N and microbial contamination, and a weaker factor associated with warm, nitrate and oxygen-poor, but phosphorus-rich water. These two factors suggest a wastewater source and a summertime, low-flow source of P, possibly associated with mobilization of phosphorus from anoxic, ironrich sediments, respectively. The latter source may have been the effluent from Western General Dairy's wastewater lagoons at Richmond; a discharge that has been eliminated through land application of the wastewater.

Table 3. Rotated eigenvectors (factors) and eigenvalues of factor scores for the Bear River mainstem based on principal components analysis of 1980 "208" data set.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
TEMP	-0.84	0.29	0.05	-0.28
DO	0.73	0.10	-0.17	-0.24
NH3	-0.05	-0.11	0.24	0.84
NO3	0.78	-0.20	-0.10	0.20
NO2	0.29	0.07	-0.08	0.82
PO4	0.67	0.02	-0.03	0.52
TURB	-0.42	0.14	0.81	0.06
COND	-0.16	-0.17	-0.82	0.01
SS	-0.20	0.19	0.82	0.10
TOTCOLI	-0.15	0.91	0.16	-0.06
FECCOLI	0.06	0.91	0.12	-0.08
FECSTREP	-0.31	0.66	0.36	0.18

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	4.05	33.7	33.7
2	2.44	20.3	54.1
3	1.66	13.8	67.9
4	1.05	8.7	76.6

Table 4. Rotated eigenvectors (factors) and eigenvalues of factor scores for the Cub River mainstem based on principal components analysis of 1980 "208"data set.

	FACTOR 1	FACTOR 2
TEMP	-0.05	0.10
DO	0.52	-0.85
NH3	0.82	-0.57
NO3	-0.34	-0.94
NO2	-0.76	0.65
PO4	-0.07	0.10
TURB	0.86	-0.52
COND	-0.10	0.01
SS	0.94	-0.34
TOTCOLI	0.84	0.55
FECCOLI	0.99	0.16
FECSTREP	0.10	0.09

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	7.57	63.1	63.1
2	4.43	36.9	100.0

It should be noted that these data only cover the period April-October, 1980, and thus may not adequately represent either the whole year, or most years in general; however, 1980 was reasonably typical from a hydrologic standpoint.

Studies on Reservoirs, Tributaries, and Livestock Runoff

Drury et al. (1975) conducted an intensive study of Hyrum Reservoir on the Little Bear River in Cache Valley for one year prior to, and one year following, artificial destratification of the reservoir. This study, along with a dissertation (Drury 1975) and a related thesis (Luce 1974) are particularly useful as they contain a great deal of data on the chemical limnology, phytoplankton dynamics, sediment chemistry, and microbial populations of a lower valley reservoir located in the study area. For example, the data from this study were used by Messer (1983) to determine the response ratio (the expected amount of chlorophyll a to result from a given water column phosphorus concentration) expected from the proposed Lower Bear River Project reservoirs. These data were also useful in adapting the reservoir water quality model used in the present work to local conditions. It may also be useful in predicting the potential for eutrophication mitigation through destratification in the proposed reservoirs. The study reported by Israelsen et al. (1975) contains a great deal of information on the biota and water quality of Spring Creek, Utah, which might prove to be useful in determining how upper watershed management in the basin might effect water quality in the receiving reservoirs, especially with respect to nutrient transport and the recruitment of xenoplankton that may initiate phytoplankton blooms.

The presence of natural organic compounds in Hyrum Reservoir, presumably resulting from the excretions and/or decay of phytoplankton in the reservoir was studied by Renk et al. (1978). This aspect of water quality could be particularly important in predicting the potential for taste and odor problems in the proposed reservoirs, as well as the potential for the formation of cancer-causing trihalomethanes when such organics are chlorinated as part of the water treatment process. The report also contains abundant data on the phytoplankton populations in the reservoir during the study.

Messer et al. (1981) examined the feasibility of managing western reservoirs to remove salinity through natural biogeochemical processes. Although the report concluded that the success of such schemes was unlikely, the report contains chemical limnological data for the Bear River below Soda Point Reservoir, including Oneida Narrows Reservoir. Unfortunately, virtually no biological data were collected.

Rupp and Adams (1981) reported considerable information on the chemistry and periphyton ecology of the lower Logan River that is not available from routine monitoring studies. The problem of livestock waste runoff and its impact on water quality of receiving streams in Cache Valley, Utah, was assessed in a study by Wieneke et al. (1980) using a combination of monitoring and mathematical simulations. Over 220 beef and dairy cattle feedlots were identified in Cache Valley which had potential discharge into the Bear River and its tributaries. A computer model designed to predict mass loadings of pollutants from feedlots adequately predicted loadings during rainfall events, but overestimated loadings during snowmelt by more than 100 percent. Differences in mobility of feedlot wastes under freeze-thaw conditions may explain this discrepancy.

Concentrations of pollutants in feedlot runoff depended on the type of feedlot surface and antecedent precipitation and/or snowmelt patterns. Concentrations of COD and BOD_5, COD and total phosphorus, and suspended and volatile solids in feedlot runoff were highly correlated ($r^2 \geq 0.84$). Total phosphorus and PO_4-P concentrations were not linearly correlated. Another major finding of the study was that separation of cattle from the receiving stream by approximately 60 m (200 ft) significantly reduced the impact of the waste on the stream water quality. It was also found that the hydraulic transport time from any of the livestock feeding operation in Cache Valley to Cutler Reservoir is less than or equal to one day at low flow. This short transport time suggests that sedimentation of manure inputs of pathogens and indicator microorganisms, together with availability of nutrients from feedlot runoff in reservoirs in Cache Valley, may be important, especially because degradation and nutrient consumption by stream biota may be minimal, in cold water.

Empirical Trophic State Modeling of Proposed Reservoirs

Messer (1983) applied empirical trophic state modeling to several alternative scenarios for the proposed Smithfield, Amalga, Honeyville, and Washakie Reservoirs in order to determine the degree of eutrophication expected to result from phosphorus loading in the various reservoirs. Eutrophication is the establishment of heavy growths of floating algae (phytoplankton) in lakes and reservoirs resulting from phosphorus (and less often, nitrogen) inputs from erosion, wastewater or agricultural operations. It interferes with reservoir operations by producing filter-clogging algae, which also may impart unpleasant tastes and odors to the water and reduce the concentration of dissolved oxygen as they decompose in bottom waters, thus decreasing available fish habitat and leading to the release of iron and manganese which may stain laundry and appliances if not removed from finished M & I waters. The empirical models applied in this analysis were based on experience in other western reservoirs and used the same data as BWR (1982) to determine phosphorus loadings.

The result of this analysis was that all of the reservoirs were expected to show eutrophic conditions sufficient to cause problems both with fish habitat, M & I water treatability, and recreational use. The expected annual mean growing season chlorophyll a concentrations ranged from 17 $\mu g \cdot \ell^{-1}$ for the Honeyville Reservoir to 31 $\mu g \cdot \ell^{-1}$ for the Smithfield Reservoir. These values can be compared with a commonly accepted value of 10 $\mu g \cdot \ell^{-1}$ as the lower limit for eutrophic waters. Eutrophic conditions were expected to be much worse than in Strawberry, Hyrum, and Deer Creek Reservoirs, which already experience water quality problems associated with fish habitat and water treatability. It was recommended that additional data be collected on the bioavailability of phosphorus in the Bear River, as well as increasing the resolution of the models by collecting more intensive data on phosphorus concentrations year-round at the various sites.

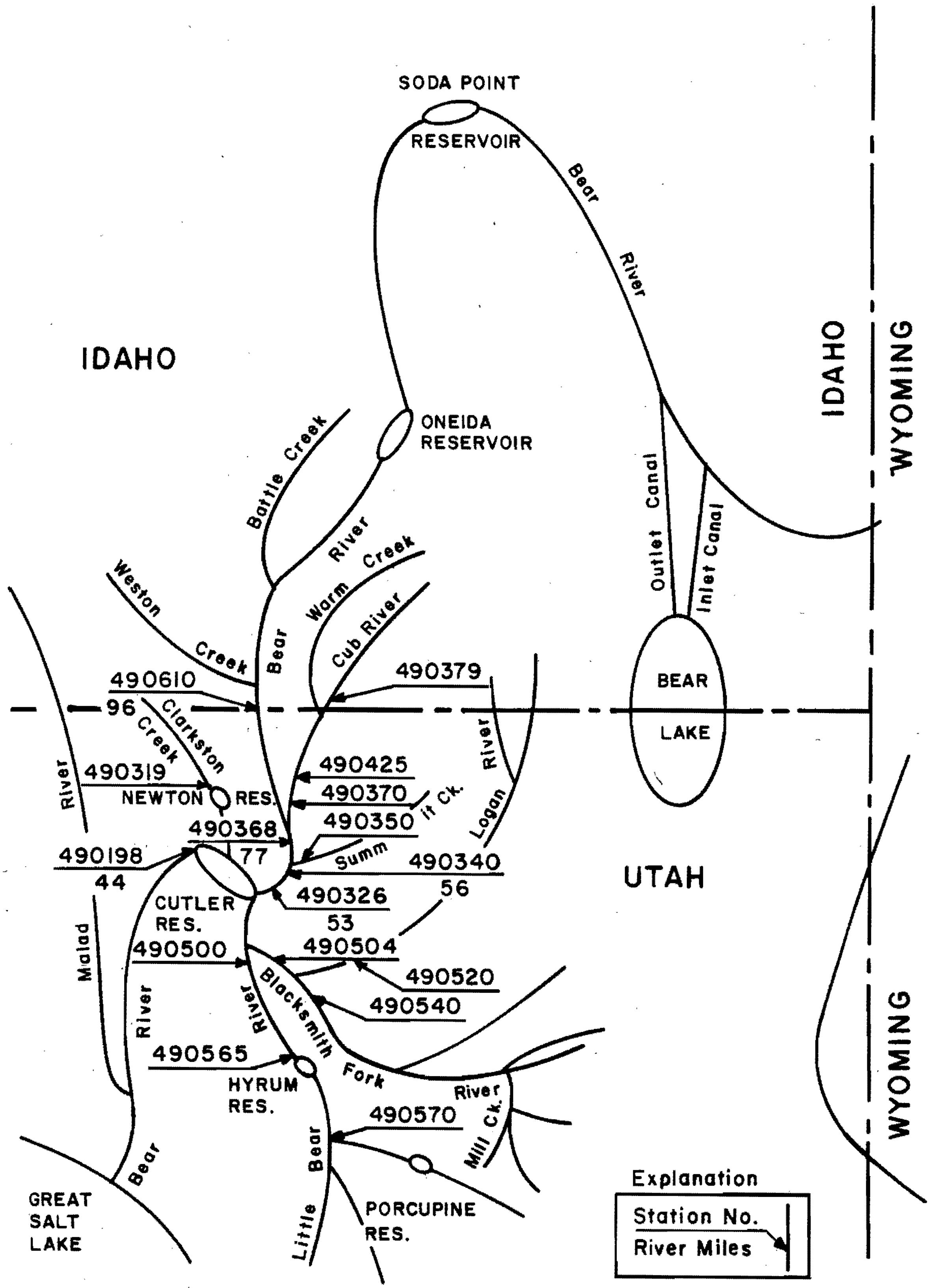


Figure 12. Schematic diagram of the study area showing sampling locations with STORET data collected from January 1977 through December 1983.

Table 5. Summary statistics for the Bear River below the confluence with the Cub River (STORET 490368) between January 1977 and December 1983. All bacterial data are Log_{10}.

VARIABLE	UNITS	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMPERATURE	DEG. C	13.140	7.603	.500	24.090	25
DO	MG/L	8.844	2.263	5.399	15.000	24
CNDUCTVY FIELD	MICROMHO	662.158	153.204	200.000	920.000	19
CNDUCTVY @25C	MICROMHO	793.808	338.719	495.000	2350.000	26
PH	SU	8.056	.357	7.299	8.599	23
TSS	C MG/L	90.917	59.739	20.000	265.000	24
NO2+NO3	MG/L	.708	.505	.200	2.419	18
TOT KJEL N	MG/L	.768	.268	.100	1.500	22
OIL + GRSE	MG/L	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	MG/L	9.517	7.461	2.099	33.000	21
COD	MG/L	16.550	7.000	6.000	32.000	20
NH3+NH4	MG/L	.262	.371	0.0	1.000	26
CALCIUM (DISS)	MG/L	58.350	6.675	45.000	72.000	20
MANGNSES (DISS)	UG/L	2.000	2.739	0.0	5.000	5
POTSSIUM (DISS)	MG/L	7.409	2.702	4.000	16.000	22
SODIUM (DISS)	MG/L	45.136	17.214	19.000	98.000	22
HCO3 ION	MG/L	324.273	42.040	236.000	410.000	22
CO3 ION	MG/L	.095	.436	0.0	2.000	21
TOT CHLORIDE	MG/L	53.727	18.739	21.000	107.000	22
SULFATE (DISS)	MG/L	56.455	16.355	23.000	85.000	22
TOTAL PHOS	MG/L	.154	.163	.020	.820	21
TOTAL ALK	MG/L	266.955	34.946	194.000	336.000	22
TOTAL HARDNESS	MG/L	293.727	41.433	210.000	372.000	22
TURBIDITY	HACH FTU	38.832	20.203	11.000	87.000	22
TDS	MG/L	452.560	89.212	268.000	638.000	25
TOTAL ARSENIC	UG/L	3.235	.710	2.000	4.000	17
TOTAL CADMIUM	UG/L	1.000	0.0	1.000	1.000	15
TOTAL COPPER	UG/L	10.000	0.0	10.000	10.000	16
IRON	MG/L	.809	1.069	.100	5.409	22
TOTAL LEAD	UG/L	5.133	.516	5.000	7.000	15
MANGNESE	UG/L	69.118	36.795	15.000	160.000	17
TOTAL MERCURY	UG/L	.135	.208	0.0	1.000	20
TOTAL SELENIUM	UG/L	.800	1.162	.500	5.000	15
TOTAL ZINC	UG/L	19.118	14.495	5.000	60.000	17
TOTAL COLI MF	/100ML	VARIABLE IS MISSING FOR EVERY CASE.				
TOTAL COLI MPN	/100ML	2.372	.782	1.362	3.380	9
FEC COLI MF	/100ML	VARIABLE IS MISSING FOR EVERY CASE.				
FEC COLI MPN	/100ML	2.903	.821	1.602	3.968	9
FEC STREP MF		VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	MG/L	3.622	1.286	1.599	6.000	9
FLOW RATE	MGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOW RATE	GPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOW RATE	CFS	VARIABLE IS MISSING FOR EVERY CASE.				
FLUORIDE (DISS)	MG/L	.281	.059	.200	.360	7
NO3 (DISS)	MG/L	.565	.417	.050	1.199	10
NO2 (DISS)	MG/L	.033	.052	0.0	.100	6
ORTHO PHOS	MG/L	.071	.045	.020	.170	8
SILICA (DISS)	MG/L	14.571	3.867	8.000	21.000	7
CO2	MG/L	3.955	1.558	2.000	8.000	22

Table 6. Summary statistics for the Bear River below Cutler Reservoir (STORET 490198) between January 1977 and December 1983. All bacterial data are Log_{10}.

VARIABLE	UNITS	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMPERATURE	DEG. C	11.406	8.710	0.0	26.000	36
DO	MG/L	9.863	3.163	5.199	17.790	34
CNDUCTVY FIELD	MICROMHO	775.000	406.430	125.000	2118.000	29
CNDUCTVY @25C	MICROMHO	924.357	426.838	450.000	2140.000	42
PH	SU	8.249	.558	7.399	10.500	34
TSS	C MG/L	52.195	48.316	.500	175.000	39
NO2+NO3	MG/L	.527	.303	.100	1.149	35
TOT KJEL N	MG/L	.863	.951	.200	5.000	41
OIL + GRSE	MG/L	13.690	.	13.690	13.690	1
TOC	MG/L	10.247	8.993	1.000	38.790	34
COD	MG/L	20.053	13.575	4.000	85.000	38
NH3+NH4	MG/L	.221	.296	0.0	1.000	43
CALCIUM (DISS)	MG/L	60.333	9.511	42.000	81.000	36
MANGNSES (DISS)	UG/L	0.0	0.0	0.0	0.0	6
POTSSIUM (DISS)	MG/L	8.486	4.127	1.000	18.000	37
SODIUM (DISS)	MG/L	94.027	90.651	18.000	360.000	37
HCO3 ION	MG/L	304.703	41.572	196.000	384.000	37
CO3 ION	MG/L	3.500	9.602	0.0	54.000	36
TOT CHLORIDE	MG/L	135.944	140.786	22.000	530.000	36
SULFATE (DISS)	MG/L	50.703	15.156	21.000	75.000	37
TOTAL PHOS	MG/L	.117	.047	.050	.200	40
TOTAL ALK	MG/L	253.595	32.797	179.000	315.000	37
TOTAL HARDNESS	MG/L	290.649	39.888	194.000	360.000	37
TURBIDITY	HACH FTU	28.603	25.236	1.899	100.000	36
TDS	MG/L	541.644	241.444	252.000	1272.000	45
TOTAL ARSENIC	UG/L	3.274	1.527	1.500	7.000	31
TOTAL CADMIUM	UG/L	1.000	0.0	1.000	1.000	29
TOTAL COPPER	UG/L	10.500	2.403	5.000	15.000	30
IRON	MG/L	.518	.419	.080	1.919	37
TOTAL LEAD	UG/L	5.828	1.872	3.000	10.000	29
MANGNESE	UG/L	54.161	29.389	10.000	130.000	31
TOTAL MERCURY	UG/L	.151	.229	0.0	1.299	35
TOTAL SELENIUM	UG/L	.733	.254	.500	1.000	30
TOTAL ZINC	UG/L	22.000	21.063	5.000	110.000	31
TOTAL COLI MF	/100ML	VARIABLE IS MISSING FOR EVERY CASE.				
TOTAL COLI MPN	/100ML	2.448	1.138	1.362	5.380	17
FEC COLI MF	/100ML	VARIABLE IS MISSING FOR EVERY CASE.				
FEC COLI MPN	/100ML	2.316	1.069	.602	4.362	17
FEC STREP MF		VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	MG/L	3.950	3.690	1.199	17.000	18
FLOW RATE	MGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOW RATE	GPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOW RATE	CFS	VARIABLE IS MISSING FOR EVERY CASE.				
FLUORIDE (DISS)	MG/L	.292	.127	.030	.600	18
NO3 (DISS)	MG/L	.533	.380	0.0	1.449	20
NO2 (DISS)	MG/L	.068	.097	0.0	.400	17
ORTHO PHOS	MG/L	.056	.027	.020	.100	18
SILICA (DISS)	MG/L	13.278	2.782	7.000	17.000	18
CO2	MG/L	3.297	1.746	1.000	8.000	37

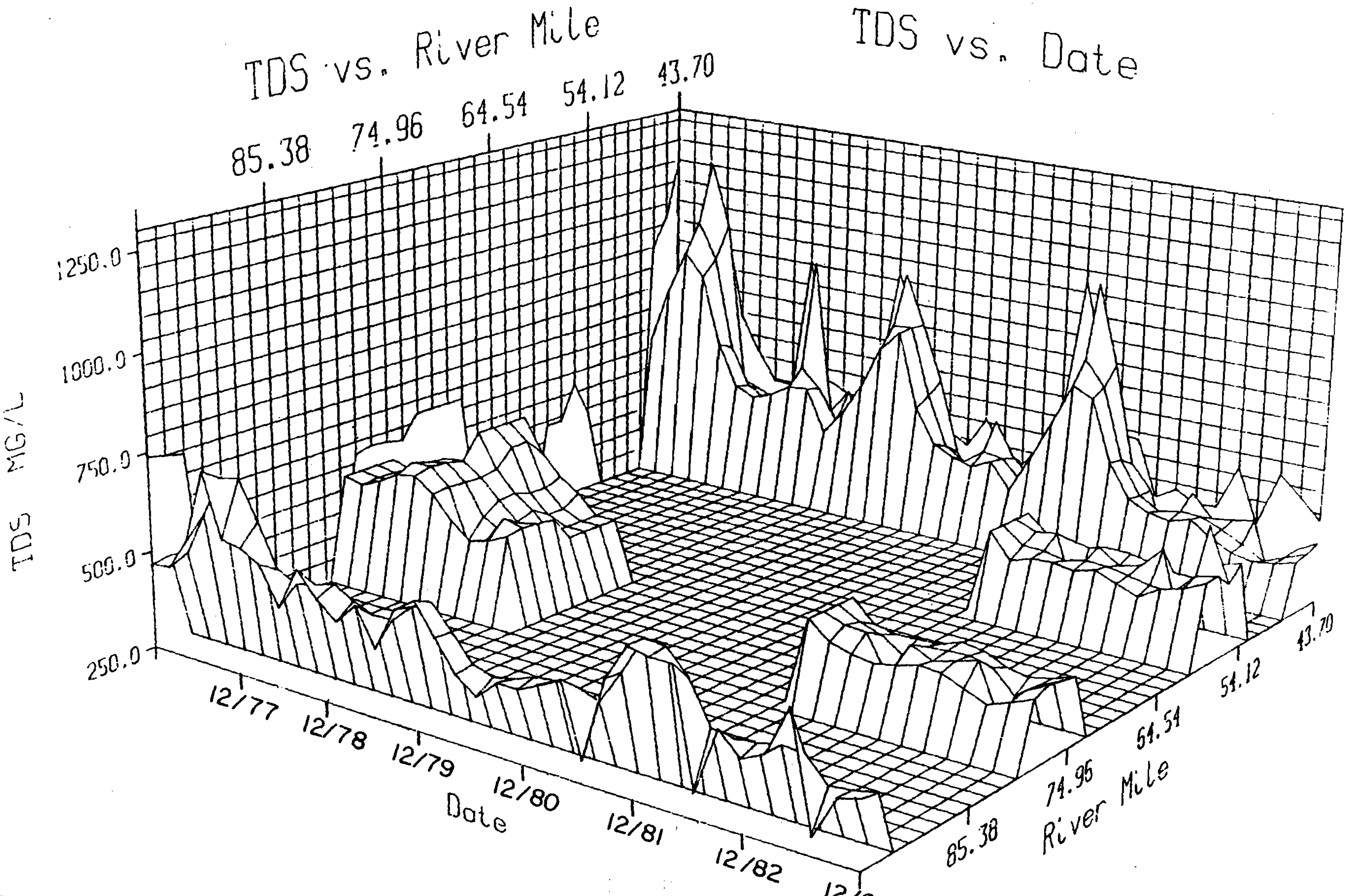


Figure 13. Three dimensional plot of total dissolved solids (TDS) concentrations at five Bear River sampling stations in Cache Valley and below Cutler Reservoir over the period of record in the STORET data base.

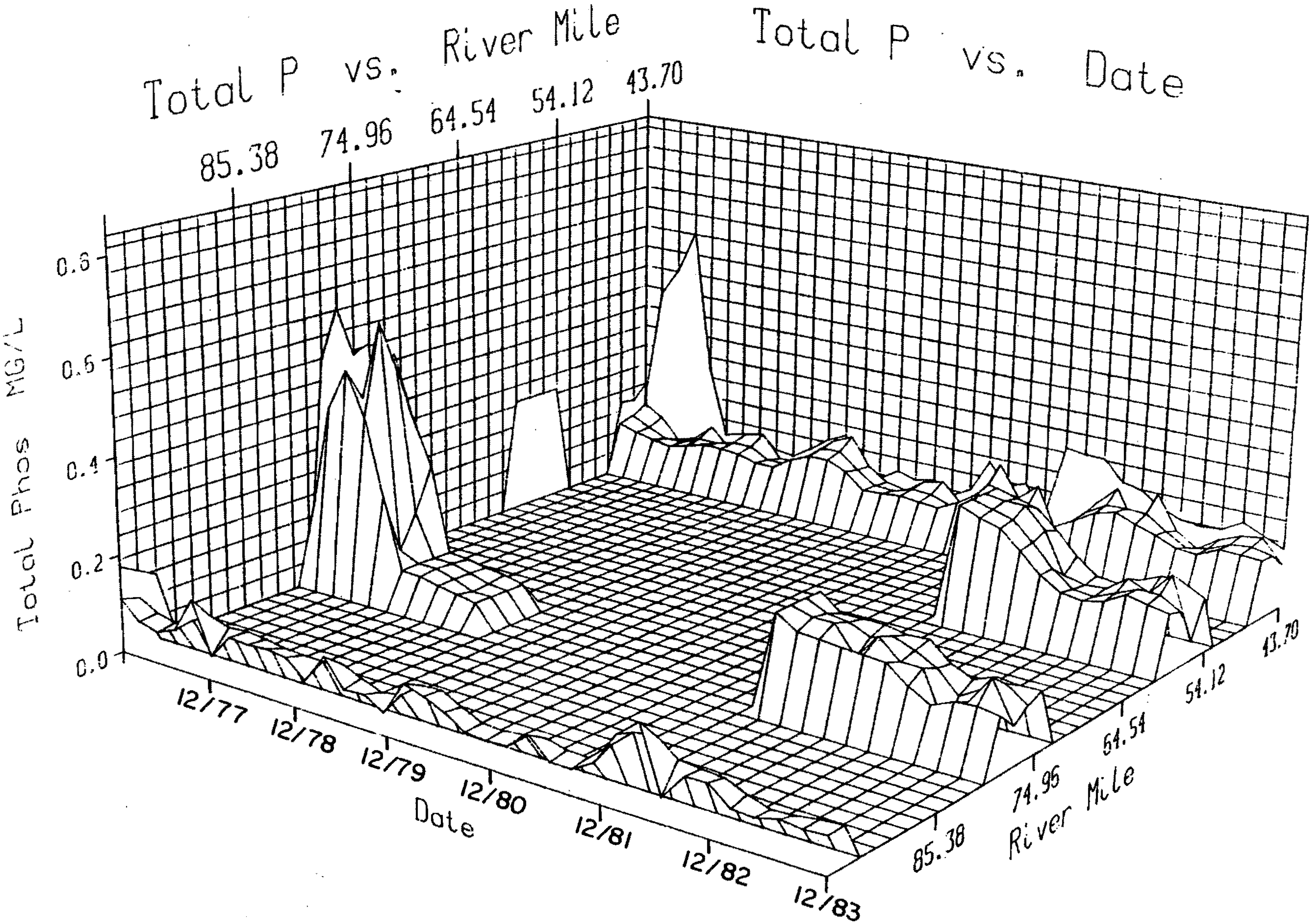


Figure 14. Three dimensional plot of total phosphorus concentrations at five Bear River sampling stations in Cache Valley and below Cutler Reservoir over the period of record in the STORET data base.

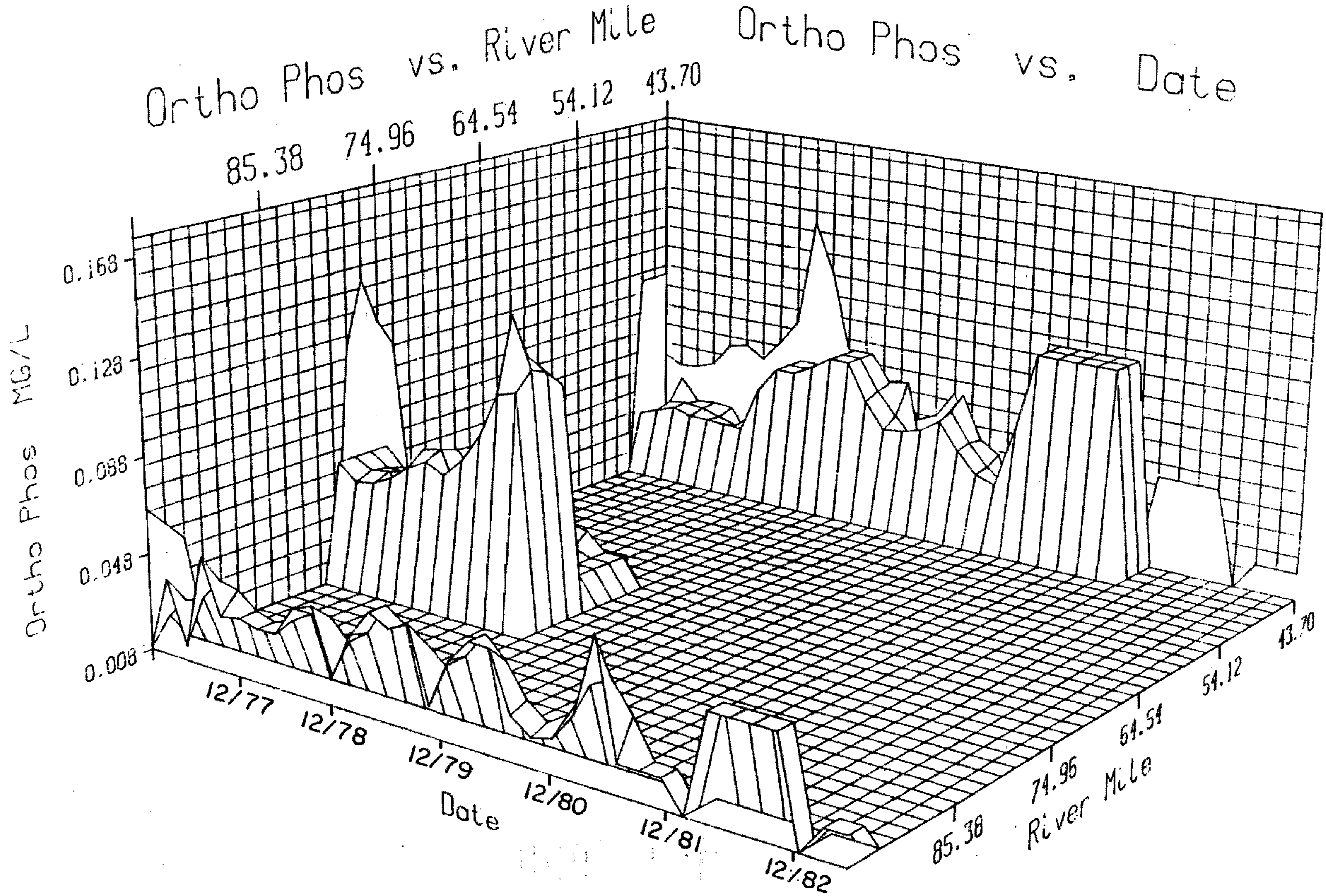


Figure 15. Three dimensional plot of orthophosphorus concentrations at five Bear River sampling stations in Cache Valley and below Cutler Reservoir over the period of record in the STORET data base.

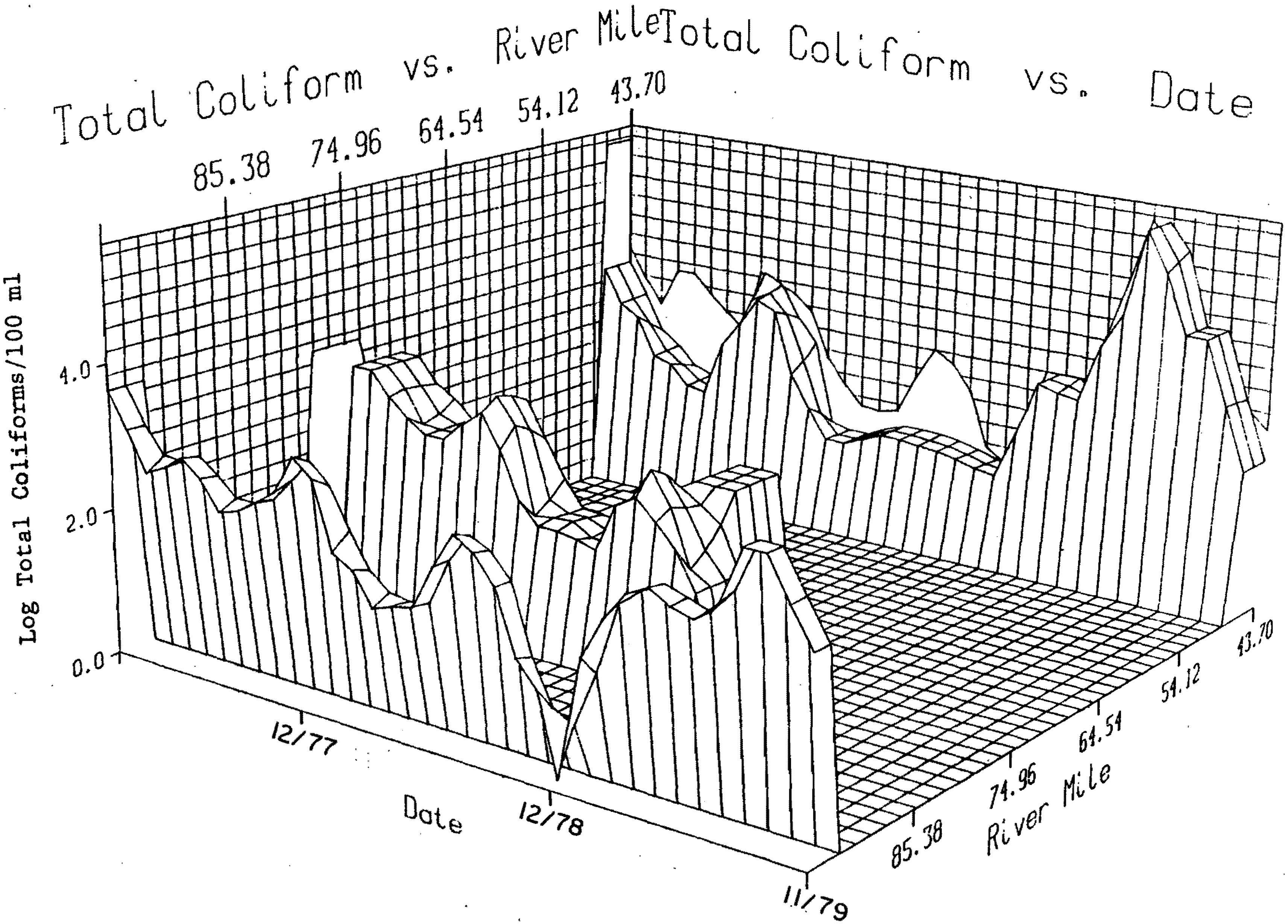


Figure 16. Three dimensional plot of total coliform concentrations at five Bear River sampling stations in Cache Valley and below Cutler Reservoir over the period of record in the STORET data base.

information in time and distance along the stream it is not reasonable to try to represent the entire parameter surface that three dimensional graphs could illustrate. However, portions of the surface are represented here as peaks and plateaus where data are available.

Major fluctuations in salinity on an approximately annual basis at the station below Cutler Reservoir (river mile 43.7) can be seen. This annual increase in salinity does not appear to have occurred in 1982 and possibly 1983. The sustained higher flows in the river due to increased precipitation in these years may account for less fluctuation in salinity.

Patterns of total and orthophosphorus concentrations do not appear to be similar, and periodic patterns are not obvious (Figures 14 and 15). However, occasionally high concentrations of either of these parameters have been observed. Also, there appears to have been some tendency for orthophosphorus concentration to increase in the downstream direction.

Total coliform concentrations showed surprisingly little tendency to increase or decrease as the Bear River flowed through the Cache Valley and Cutler Reservoir during the nearly three years of record shown in Figure 16. High concentrations, in excess of the $5000 \cdot 100\ m\ell^{-1}$ (log 3.7) standard for the river, were measured below Cutler Reservoir in 1978.

Principal Component Analysis

Principal component analysis was applied to STORET data for the Bear River in Cache Valley to below Cutler Reservoir in order to identify data interrelationships that may help elucidate types and/or sources of water quality parameters (SPSS Inc. 1983). Summary statistics for the data used in this analysis are shown in Table 7.

Fourteen factors were extracted which described 74.4 percent of the total data set variance. The first four factors and the eigenvalues of the factor scores are shown in Table 8. The first factor identified the natural interrelationship of conductivity, dissolved solids, and salts as the major variables in water quality, and explained 19.1 percent of the data variance.

Factor 2 had relatively high positive factor loadings for nitrate, silica, and a high negative factor loading for temperature, sodium and chloride. This indicates that nitrate and silica are higher in the river when the water is cold and at high flow (greatest dilution of salt). Nitrate movement through soil is not appreciably retarded by ion exchange and is often highest in first flush runoff leachate water. It seems plausible that nitrate and silica move from the soil to the river in first flush snowmelt water while the river is still cold in the early spring or during winter snowmelt events. Factor 2 describes 9.2 percent of the total model variance. The remaining 12 factors account for 44 percent of the total model variability, with individual factors describing between 2.6 and 6.0 percent variance decreasing from factors 3 through 14. This suggests that in this portion of the Bear River there are few if any consistent relationships among other water quality parameters, i.e., pollution indicators are found in river samples independent of one another.

Table 7. Summary statistics from STORET for water quality in the Bear River in Cache Valley and below Cutler Reservoir. Coliform data are Log_{10}.

VARIABLE	UNITS	MEAN	STD DEV	CASES
TEMP	DEG. C	11.70	7.48	115
DO	MG/L	9.23	2.29	109
CONDFLD	MICROMHO	730.85	220.20	95
COND25C	MICROMHO	844.52	331.99	128
PH	SU	8.12	0.36	106
TSS	C MG/L	63.40	56.98	119
NO2NO3	MG/L	0.57	0.31	105
TKN	MG/L	0.79	0.66	118
TOC	MG/L	9.69	6.61	105
COD	MG/L	17.20	8.64	114
NH3NH4	MG/L	0.25	0.32	130
CA	MG/L	59.44	9.84	112
K	MG/L	8.30	4.56	116
NA	MG/L	66.22	57.18	116
HCO3	MG/L	320.47	42.39	116
CO3	MG/L	2.18	7.15	112
CL2	MG/L	88.51	86.69	114
SO4	MG/L	55.93	14.72	116
TOTP	MG/L	0.20	0.85	117
TOTALK	MG/L	265.10	34.50	116
TOTHARD	MG/L	296.67	39.25	116
TURB	HACH FTU	29.32	21.75	115
TDS	MG/L	495.04	173.54	133
CU	UG/L	10.48	3.45	93
IRON	MG/L	0.81	2.66	115
PB	UG/L	5.84	1.65	88
MN	MG/L	54.75	24.26	96
HG	UG/L	0.13	0.15	108
SE	UG/L	0.71	0.42	90
ZN	UG/L	20.71	16.50	94
TCOLIMPN	/100ML	2.39	0.54	47
FCOLIMPN	/100ML	2.41	0.54	47
BOD5	MG/L	3.31	1.49	47
F	MG/L	0.30	0.07	50
NO3	MG/L	0.54	0.24	58
NO2	MG/L	0.06	0.04	46
ORTHOP	MG/L	0.05	0.02	52
SI	MG/L	14.59	2.14	51
CO2	MG/L	3.59	1.45	116

Table 8. The first four rotated eigenvectors (factors) and eigenvalues of factor scores for the Bear River from the Utah-Idaho border to below Cutler Reservoir based on principal components analysis of STORET water quality data.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
TEMP	-0.22	-0.59	0.33	0.30
DO	0.47	0.14	-0.27	-0.33
CONDFLD	0.58	-0.13	-0.11	0.15
COND25C	0.73	-0.50	0.03	0.11
PH	0.22	-0.13	0.24	-0.18
TSS	-0.27	0.06	0.41	0.46
NO2NO3	0.21	0.38	-0.05	0.14
TKN	-0.03	0.03	0.05	0.10
TOC	0.27	0.01	-0.00	0.05
COD	-0.15	-0.38	-0.04	0.34
NH3NH4	-0.22	0.20	-0.06	-0.08
CA	0.40	0.37	-0.05	0.32
K	0.77	-0.23	0.11	0.09
NA	0.72	-0.59	0.02	0.09
HCO3	0.78	0.45	0.17	0.15
CO3	0.13	-0.00	-0.36	-0.18
CL	0.70	-0.60	-0.01	0.07
SO4	0.73	0.28	0.06	-0.02
TOTP	-0.12	-0.01	0.13	0.02
TOTALK	0.79	0.43	0.09	0.17
TOTHARD	0.85	0.36	0.03	0.10
TURB	-0.48	0.06	0.34	0.45
TDS	0.82	-0.45	0.06	0.12
CU	-0.06	0.08	0.20	-0.13
IRON	-0.05	0.09	0.03	0.02
PB	-0.15	-0.16	-0.29	0.15
MN	-0.36	-0.14	0.37	0.55
HG	-0.31	-0.12	-0.61	0.41
SE	0.06	-0.18	-0.51	0.23
ZN	-0.11	-0.07	-0.05	0.34
TCOLIMPN	-0.07	-0.10	-0.02	-0.01
FCOLIMPN	-0.21	0.05	-0.04	0.11
BOD5	-0.03	-0.08	-0.32	0.31
F	0.56	0.00	0.37	0.02
NO3	0.12	0.57	-0.23	0.30
NO2	-0.01	0.17	-0.29	0.35
ORTHOP	-0.07	0.08	-0.14	0.38
SI	0.34	0.54	-0.06	0.30
CO2	-0.24	0.34	0.55	0.02

Table 8. Continued.

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	7.46	19.1	19.1
2	3.57	9.2	28.3
3	2.35	6.0	34.3
4	2.30	5.9	40.2
5	1.86	4.8	45.0
6	1.62	4.2	49.2
7	1.57	4.0	53.2
8	1.44	3.7	56.9
9	1.30	3.3	60.2
10	1.23	3.1	63.3
11	1.15	2.9	66.3
12	1.13	2.9	69.2
13	1.05	2.7	71.9
14	1.01	2.6	74.4

CURRENT WATER QUALITY ASSESSMENT

Monthly Sampling

The State Bureau of Water Pollution Control (BWPC) and the Utah Water Research Laboratory (UWRL) coordinated monthly sampling and analysis of water from selected stations on the lower Bear River, its tributaries, and the West Side Canal. Sampling locations are identified in Figure 17 by STORET number. The majority of the sampling and analysis was done by the BWPC while the UWRL sampled stations above and below Oneida Reservoir and analyzed all the samples for total phosphorus, biologically available (NaOH extractable) phosphorus, orthophosphorus, and an indicator bacterium, Clostridium perfringens.

Water Chemistry

Results of selected field and laboratory chemical analyses for samples collected in May 1984 through 1985 are listed in Appendix B. To conserve space in the table, all total heavy metal analyses results are not shown since concentrations were all below dissolved standards designated by the State Department of Health for domestic sources, recreation and aesthetics, aquatic life, and agriculture.

Figure 18 illustrates the concentrations of TDS found in monthly samples of the Bear River from above Oneida Reservoir to the I-15 crossing near Honeyville during the present study. A major peak in TDS was observed between October and January 1984 below Oneida Reservoir, and another peak occurred below Cutler Reservoir in May of 1985. However, the classical high salinity during late fall and winter months throughout this part of the Bear River did not occur. River flows were maintained well above average during this period as excess water stored in Bear Lake during the unusually wet years of 1982 and 1983 was discharged. This high flow kept salinity levels relatively low, even at the most downstream stations, throughout most of the study.

Relative to the State Department of Health Standards, there are relatively few water quality problems evident in the data. Table 9 lists the violations of standards that were observed during the year. As with the historical STORET data, water quality problems were not consistent at any station. Biochemical oxygen demand (BOD_5), and orthophosphorus concentrations were the most frequent problems observed.

It was noted by BWR (1983) that nitrate was often present at or near the 10 $mg \cdot \ell^{-1}$ standard in the Bear River, especially in the Cache Valley. However, very few samples taken in 1984 and 1985 have values much above 1 $mg \cdot \ell^{-1}$. The sum of total Kjeldal nitrogen (TKN), which includes ammonia nitrogen, organic nitrogen, and nitrate nitrogen never exceeded 3 $mg \cdot \ell^{-1}$ in any samples collected during the study (Figures 19 and 20). We suspect that this discrepancy arises because the data used in the original analysis were apparently reported as nitrate, rather than as nitrate-N, which is the terminology of the standard. Thus, the corresponding values are high by a factor of 62/14. In addition, it is the practice of the State Health Laboratory to hold unfiltered, unpreserved samples for nitrate analyses for as long as 2 months. We believe that in samples containing several mg of ammonium-N per liter, this practice may lead to

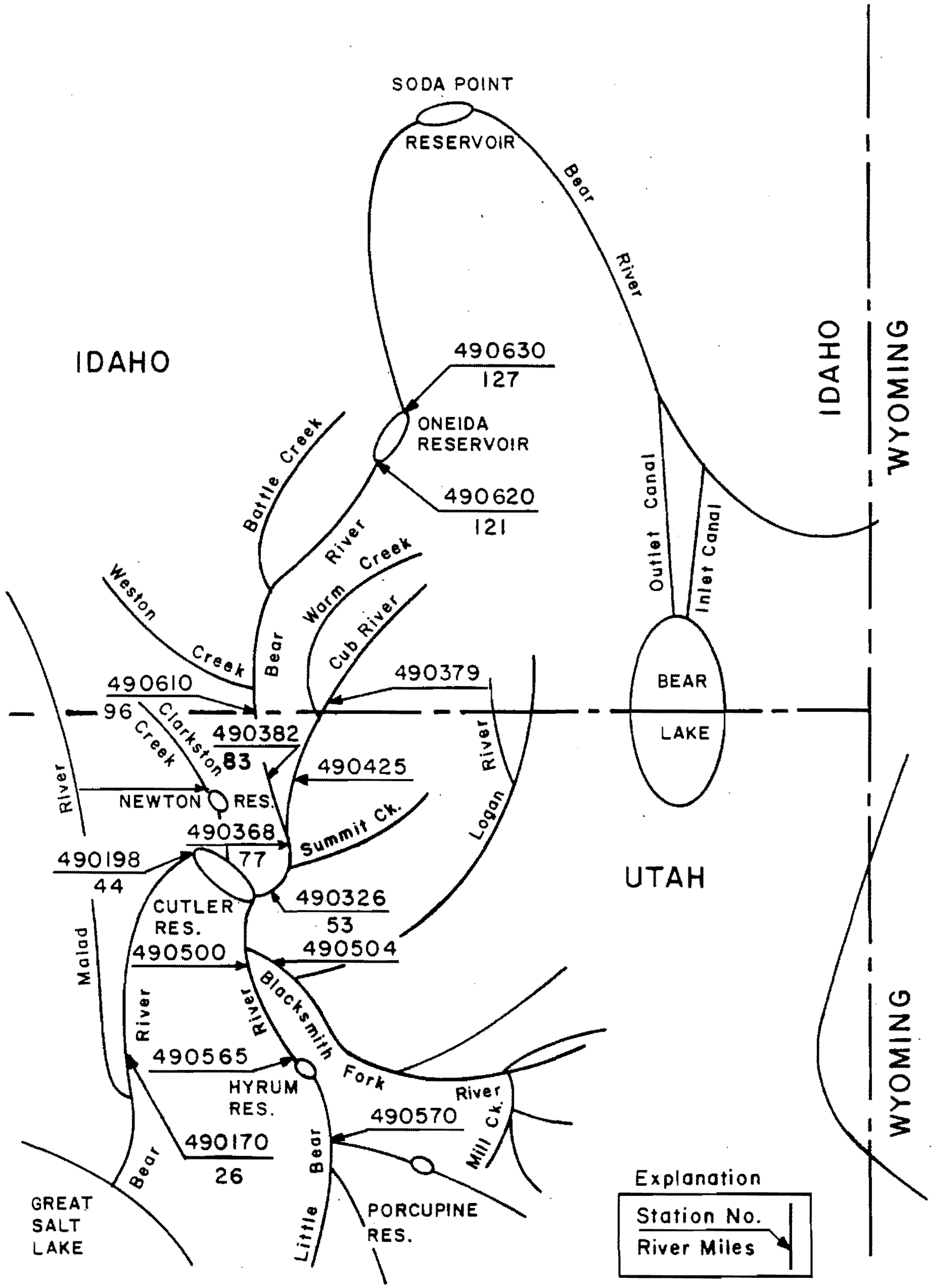


Figure 17. Schematic diagram of the study area showing monthly sampling stations for the present study.

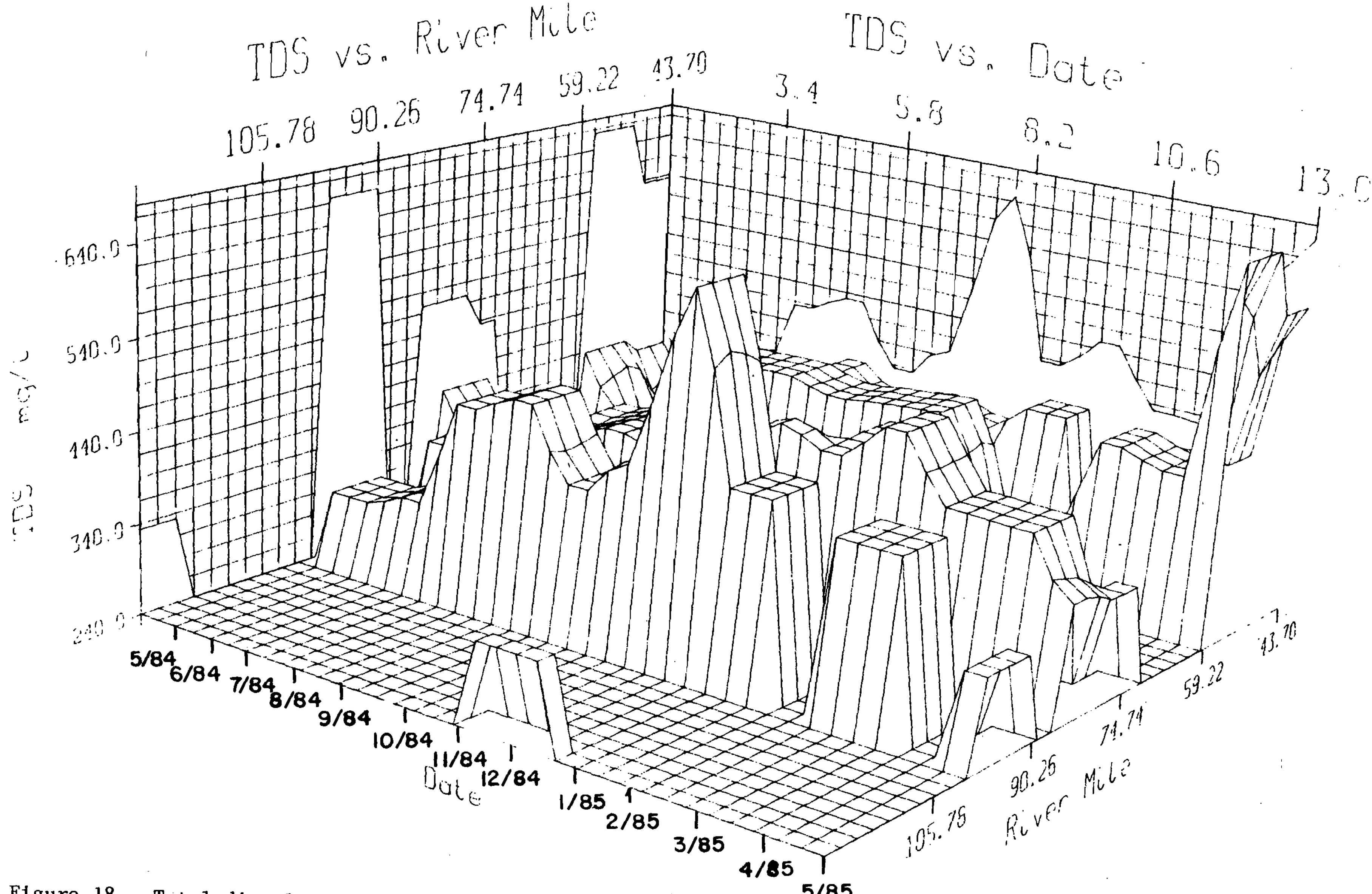


Figure 18. Total dissolved solids (TDS) concentrations in Bear River samples taken monthly during the present study. River mileage increases upstream from Great Salt Lake. The most downstream station is above Oneida Reservoir.

Table 9. Numbers of samples with violations of chemical standards for protection of beneficial uses of water (see Table 2). Thirteen samples were taken from May 1984-May 1985.

Station	Temp	pH	DO	BOD	$NH_3(aq)$-N	NO_3-N	PO_4-P
Bear R. ab. Oneida res. [490630]							3
Bear R. bl. Oneida res. [490620]							2
Bear R. W. Fairview, ID [490610]		2			1		3
Bear R. W. Richmond [490382]		2			2		5
Bear R. bl. confl. w/Cub R. [490368]					1		1
Bear R. ab. Cutler res. [490326]		1		1	1		2
Bear R. bl Cutler res. [490198]		2			2		3
Bear R. @ I-15 near Honeyville [490170]		2			3		7
W. Side Canal [490195]				1	1		1
Cub R. W. Franklin, ID [490379]		3					5
Cub R. W. Richmond [490425]		2		1	1		11
Logan R. ab. confl. w/L. Bear R. [490504]		2					
L. Bear R. W. Avon [490570]		4	1				1
L. Bear bl. Hyrum res. [490565]	1	4	1		1		1
L. Bear ab. confl. w/Logan R. [490500]		2	2	6	5	1	11

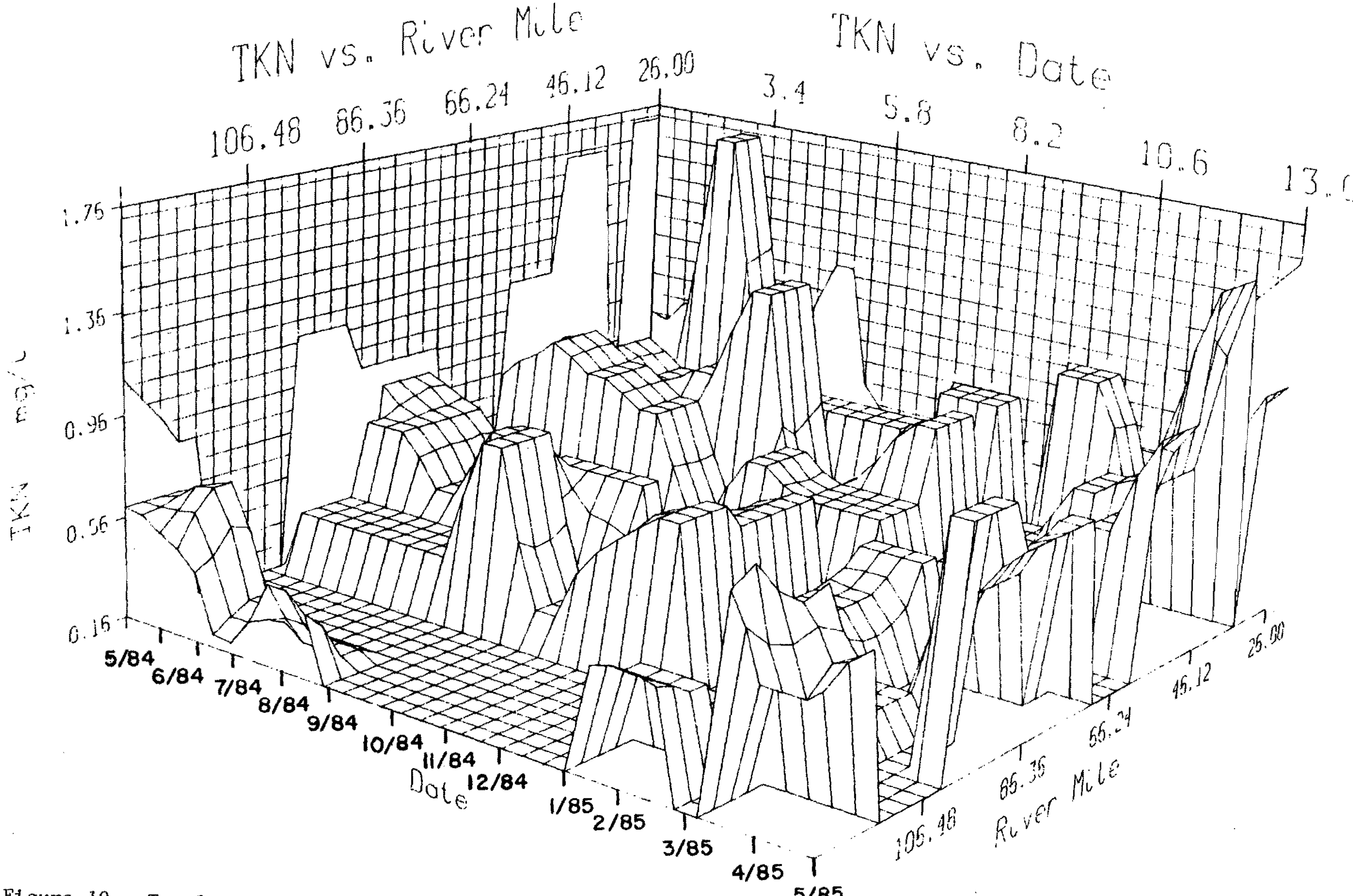


Figure 19. Total Kjeldahl nitrogen concentration in Bear River samples taken during the present study. River mileage is the same as in Figure 18.

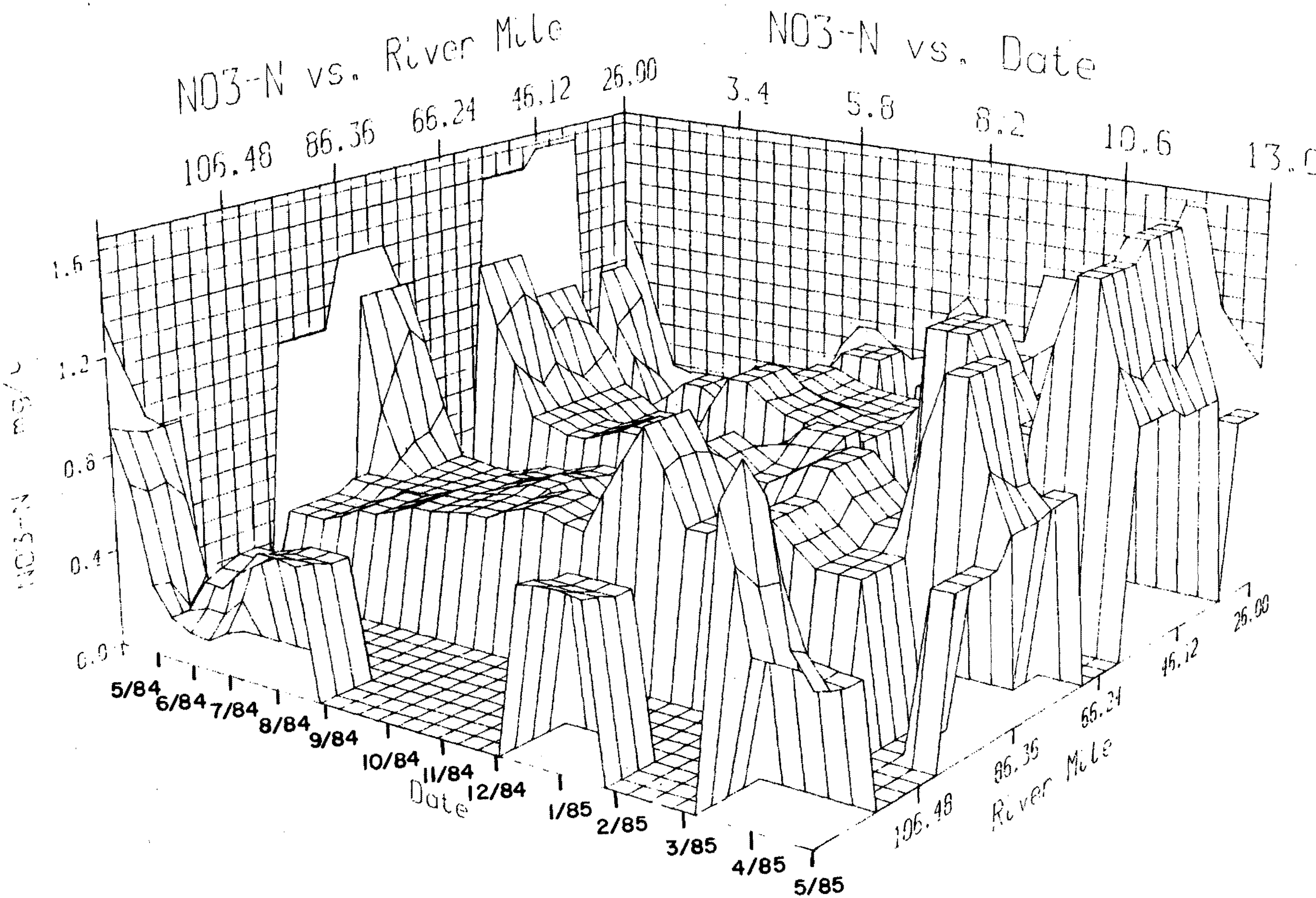


Figure 20. Nitrate nitrogen concentrations in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

overestimation of nitrate concentrations through nitrification in the sample bottles. However, the State Health Laboratory conducted an experiment in cooperation with this project in order to evaluate this possibility and did not find an appreciable increase in nitrate in arbitrarily chosen Bear River samples after 2 months storage.

Bioavailability of Phosphorus

Messer (1983) pointed out that one of the most serious roadblocks in predicting the extent of eutrophication in western reservoirs, where substantial amounts of phosphorus may originate from erosion rather than wastewater or fertilizer, is uncertainty regarding the extent of bioavailability of the total annual phosphorus load. Consequently, we have monitored the bioavailability of phosphorus in the Bear River Basin using the NaOH/NaCl extraction technique (Williams et al. 1980). This procedure has been shown to approximate the amount of the total P in certain waters that can be utilized by algae in the EPA Algal Assay Procedure (Miller et al. 1978), and has been employed at UWRL in similar water quality studies.

Table 10 contains the results of NaOH/NaCl extractable phosphorus analyses done during the study expressed as a percentage of the total phosphorus concentration in each sample. The Cub River west of Franklin, Idaho, averaged 18.5 percent of the total phosphorus concentration as NaOH/NaCl extractable, and was the most consistently high sampling station in the system. The lower fraction of NaOH/NaCl extractable phosphorus in the Cub River west of Richmond suggests that the available phosphorus at Franklin is processed into a less labile form, or is immobilized into biomass along the river. The source of this phosphorus may be from wastewaters such as the effluent from the Preston, Idaho, wastewater treatment plant, via Worm Creek, or from irrigation return flows.

A higher fraction of available phosphorus appears to be associated with late summer and fall flows in the mainstem of the Bear River. This may be due to fertilizer (non-apatite) phosphorus carried by irrigation return flows and runoff, and to phosphorus released through mineralization of organic phosphates from the plant materials in the watershed. Comparison of Figures 21, 22, and 23 shows that high concentrations of total phosphorus tend to cooccur with increased suspended solids concentrations, and that orthophosphate concentrations may also be affected by suspended solids concentrations. However, bioavailable (NaOH phosphorus) appears to be independent of suspended solids concentrations and concentrations of other phosphorus forms (Figure 24).

Microbiology

Monthly samples collected starting April 3, 1984, through April 2, 1985, were analyzed for indicator bacteria. Total coliforms, fecal coliforms, and fecal streptococci were determined in all samples, and Clostridium perfringens (total population and/or spores) was determined in samples taken through October 1984. All of these bacteria are found in large numbers in fecal material of both man and animals and indicate water pollution that may include pathogens transmitted by the fecal-oral route. C. perfringens is usually found in both human and cattle fecal material in 100 to 1000 fold lower numbers than coliforms and fecal streptococci, but it has the ability to form environmentally resistant endospores. These spores persist in the environment for long periods and help to indicate intermittent or older pollution. Bacterial pathogens usually die away due to temperature stress, starvation, and predation in most natural environments, and coliforms (especially fecal coliforms) and fecal streptococci are eliminated from the environment in much the same way. However, some infectious viruses and protozoan cysts may persist

Table 10. NaOH/NaCl extractable phosphorus as a percentage of total phosphorus.

Station	Month 1984-85														
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Bear R. ab. Oneida Res. [490630]	2	3	7	4	-	3	-	-	-	5	-	-	11		
Bear R. bl. Oneida Res. [490620]	<1	7	11	16	49	12	-	-	30	7	-	-	37		
Bear R. W. Fairview, ID [490610]	10	2	6	15	<1	29	-	25	11	10	-	13	6		
Bear R. W. Richmond [490382]	5	2	7	14	20	27	-	20	8	8	-	15	4		
Bear R. bl. confl. w/Cub R. [490368]	5	5	4	12	23	26	-	-	7	-	-	-	-		
Bear R. ab. Cutler res. [490326]	5	3	8	4	16	<3	-	14	2	22	-	18	11		
Bear R. bl. Cutler res. [490198]	5	4	6	9	11	19	-	18	1	-	-	16	10		
Bear R. @ I-15 near Honeyville [490170]	9	3	5	5	5	23	-	17	19	12	-	4	11		
W. Side Canal [490195]	-	-	6	2	7	20	-	13	3	-	-	-	-		
Cub R. W. Franklin, ID [490379]	33	26	8	15	23	14	-	26	2	12	-	11	33		
Cub R. W. Richmond [490425]	4	21	9	3	3	18	-	17	-	8	-	9	14		
Logan R. ab. Confl. w/L.Bear R. [490504	8	4	5	<2	<5	<1	-	-	6	<1	-	31	24		
L. Bear R. W. Avon [490570]	7	13	19	<1	<2	<1	-	31	11	<1	-	17	-		
L. Bear R. Bl. Hyrum res. [490565]	2	19	12	<1	<5	<1	-	44	10	7	-	21	21		
L. Bear R. abv. confl.w/Logan R. [490500]	6	10	4	10	17	7	-	15	-	7	-	12	10		

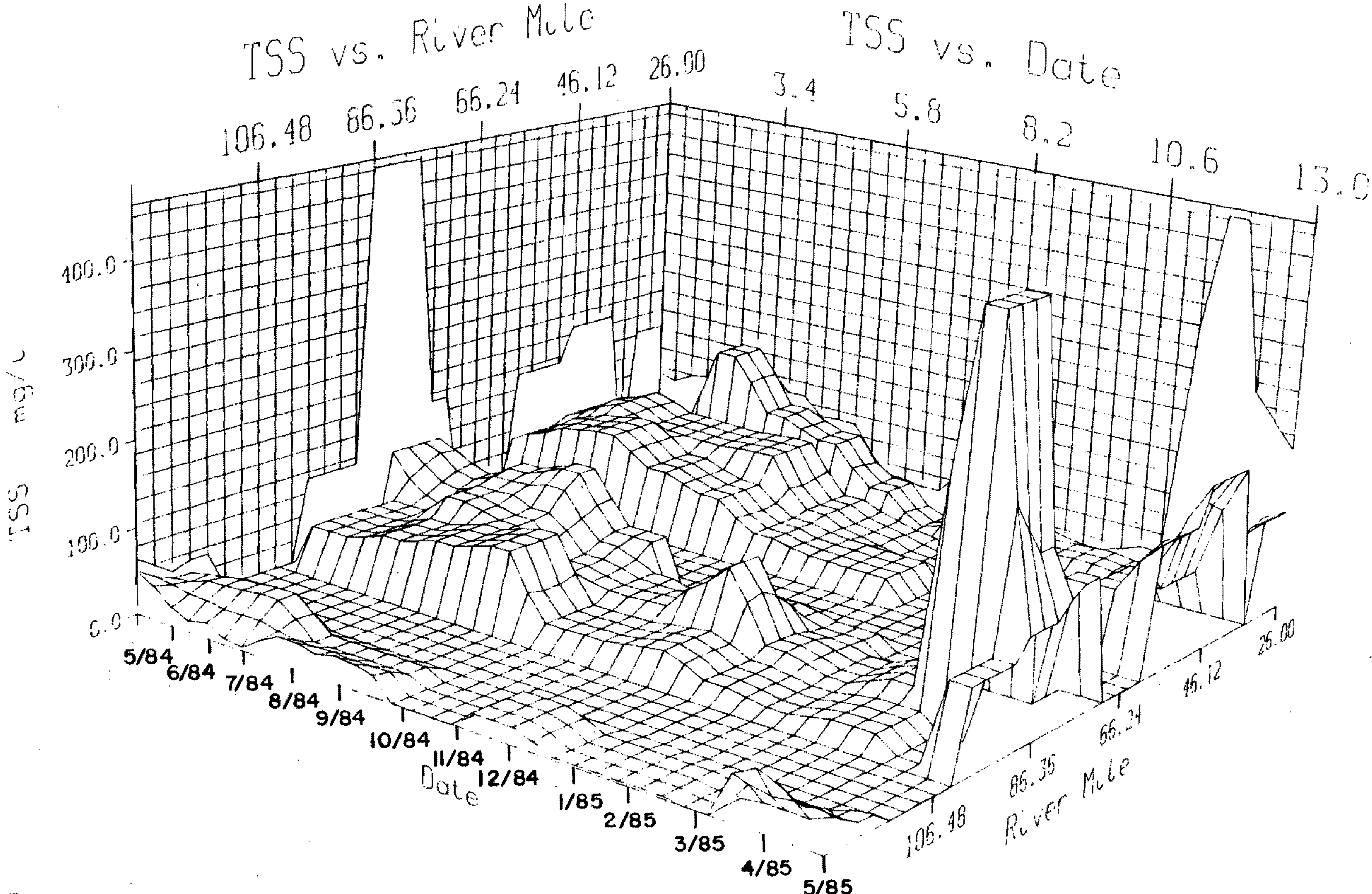


Figure 21. Total suspended solids (TSS) concentrations in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

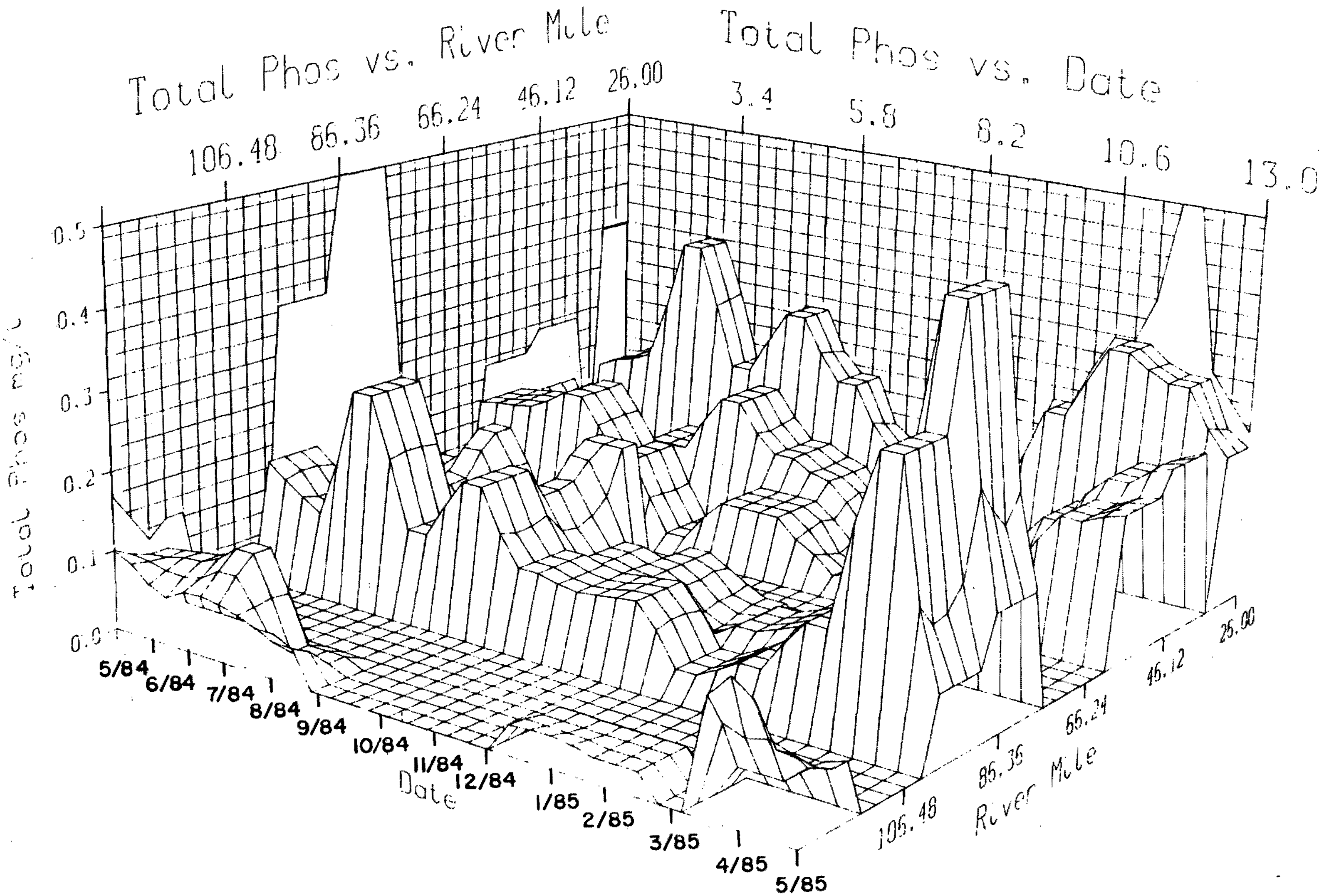


Figure 22. Total phosphorus concentrations in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

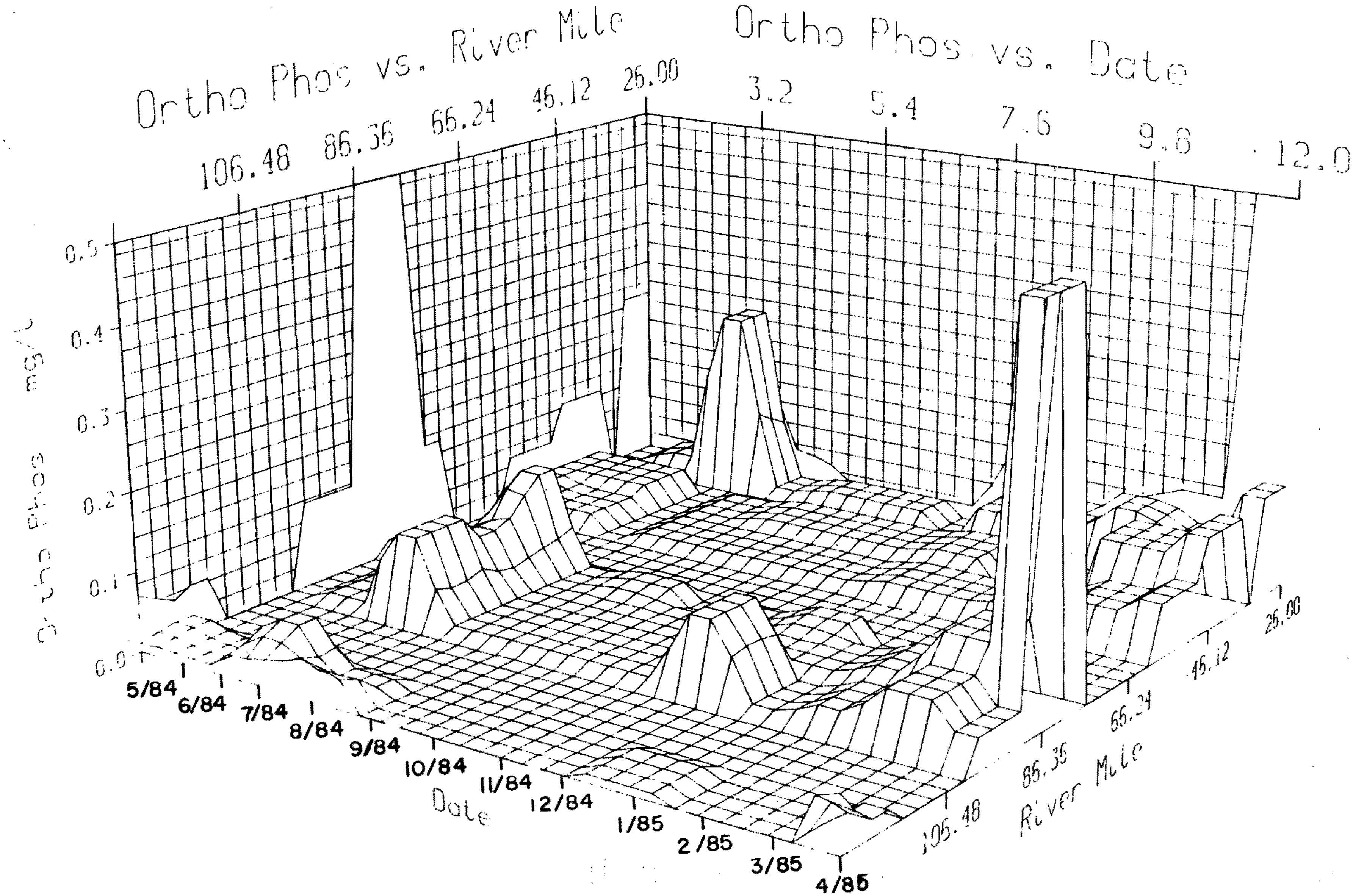


Figure 23. Orthophosphorus concentrations in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

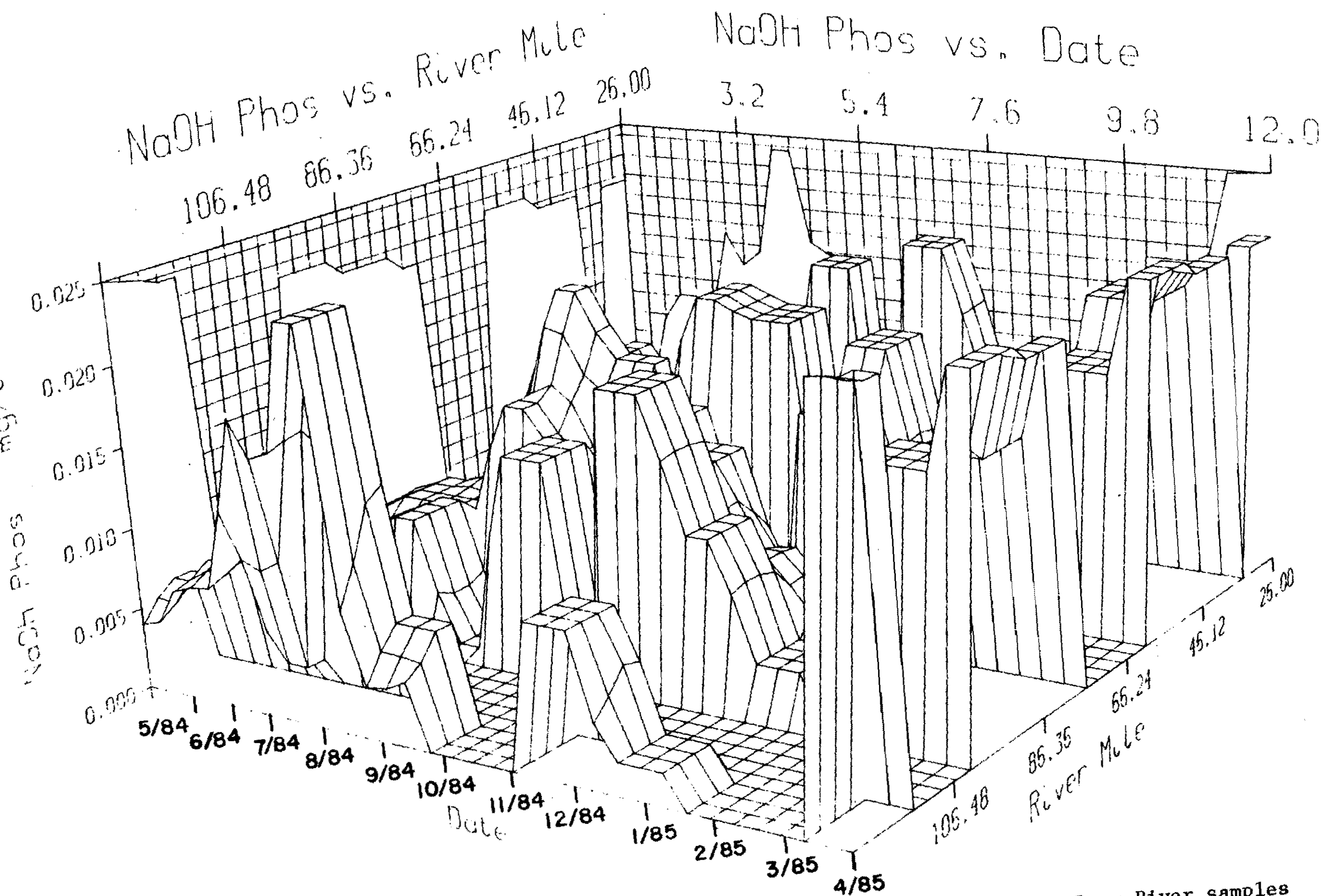


Figure 24. Sodium hydroxide/NaCl extractable phosphorus (NaOH Phos.) concentration in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

for long periods in water supplies. C. perfringens probably models the persistence of these health hazards better than the coliform group or the fecal streptococci. Coliform and fecal streptococci concentrations were determined by the BWPC, while C. perfringens analyses were made by the UWRL.

Numbers of C. perfringens were always low, and when the more specific membrane filter techniques replaced the most probable number (MPN) procedure in July, the number of C. perfringens was found to be even lower. The low ratio (i.e., ≤ 1) of C. perfringens spores to fecal coliforms, which are much less resistant to environmental stress, suggests that the fecal indicators are "freshly" added to the water and are neither the result of suspension of old polluted sediments nor residual bacteria from a remote pollution source (Bisson and Cabelli 1980).

Results of fecal indicator bacterial analyses are tabulated in Appendix C, and illustrated in Figures 25, 26, and 27. Table 11 lists violations of total and fecal coliform standards for raw water intended for complete treatment prior to culinary use. These were the only violations observed in 13 monthly samples. The maximum allowable total and fecal coliform concentrations for this designated use in Utah are 5000 and 2000 per 100 ml, respectively (Table 2). The relatively infrequent violation of these standards suggests that inputs of coliform bacteria are irregular and probably from diffuse sources. A field investigation of the source of coliform bacteria in the Little Bear River above its confluence with the Logan River found cattle grazing in partially flooded pastures immediately upstream from the sampling point. Only low concentrations of coliforms were found in the Little Bear River above the flooded pastures.

The occasional high number of indicator bacteria in the Bear River and its tributaries indicated that the probability for pathogenic microorganisms to exist in these streams was quite high. Since the majority of land use in close proximity to the Bear River and its tributaries is agricultural with pasturelands and dairy farms frequently adjacent to the river, and since municipal and industrial effluents are relatively infrequent, it seems reasonable to assume that the majority of fecal bacteria entering the streams are from animal sources. Under this assumption the presence of human pathogens in the river water might be questionable despite relatively high numbers of indicator bacteria.

To address this question, qualitative analyses for the bacterial pathogens Salmonella sp. and Campylobacter fetus subsp. jejuni was undertaken. Essentially all species of the genus Salmonella have been associated with enteric disease, and outbreaks of salmonellosis associated with drinking water occur occasionally. Campylobacter jejuni is a relatively newly recognized pathogen that is the most commonly isolated pathogen from stools of patients with diarrheal illness. Several species of animals, including healthy cattle, have been shown to harbor C. jejuni as part of their intestinal microbiota. Both Salmonella and C. jejuni are susceptible to destruction by common disinfection practices, but the low incidence or absence of any pathogens in the raw water source helps assure public health in case of treatment failure.

Cheese cloth pads were suspended in the Cub River west of Richmond, the Bear River at Amalga and at I-15 near Honeyville, and in the West Side Canal near Plymouth on September 18 and retrieved approximately 24 hours later. Bacteria associated with the pads were cultured in selective enrichment media for the respective organisms, and attempts to isolate selected organisms were made.

Enrichment for Salmonella was done in selenite cystine broth incubated at

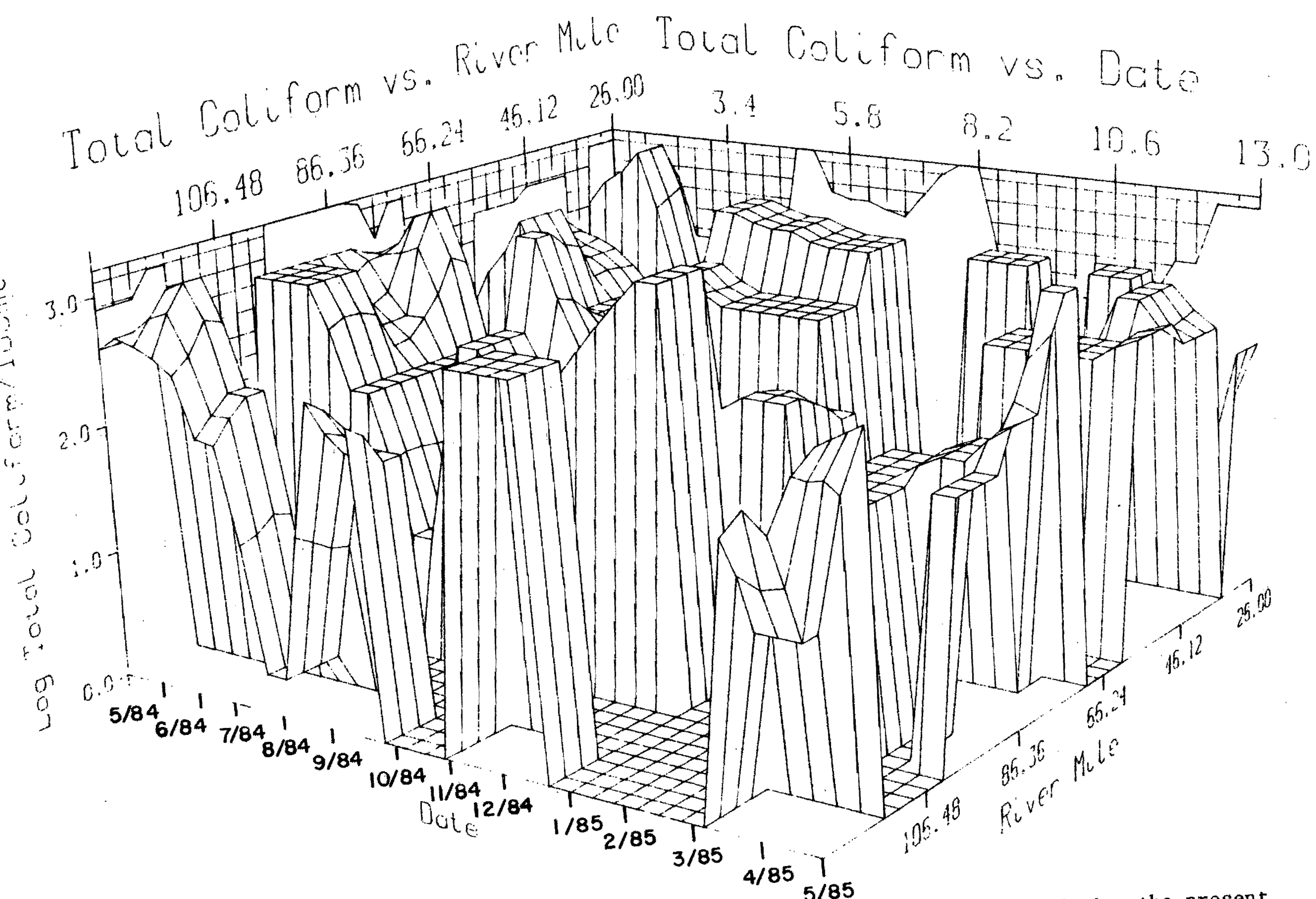


Figure 25. Total coliform concentrations ($\log_{10}$) in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

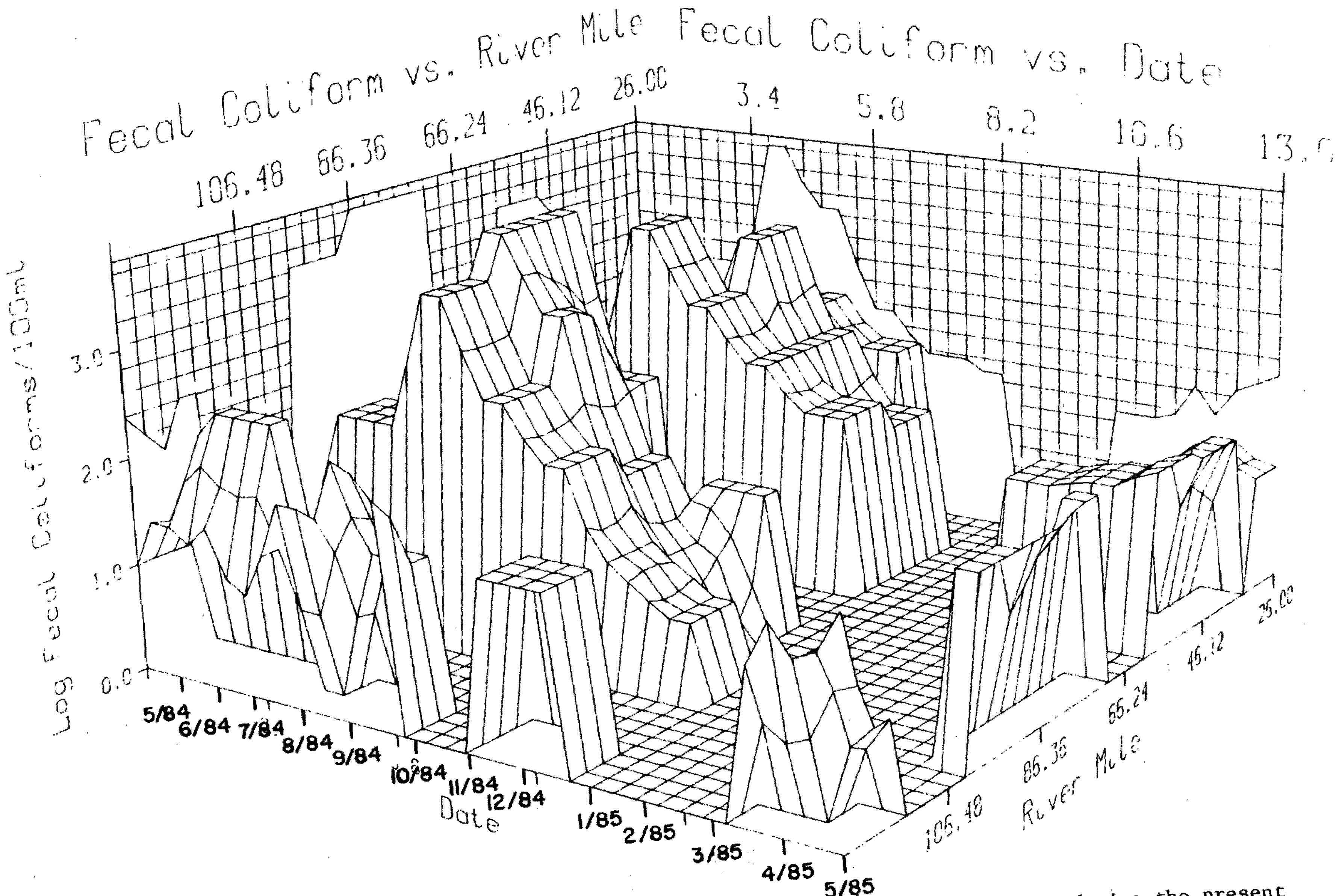


Figure 26. Fecal coliform concentrations ($\log_{10}$) in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

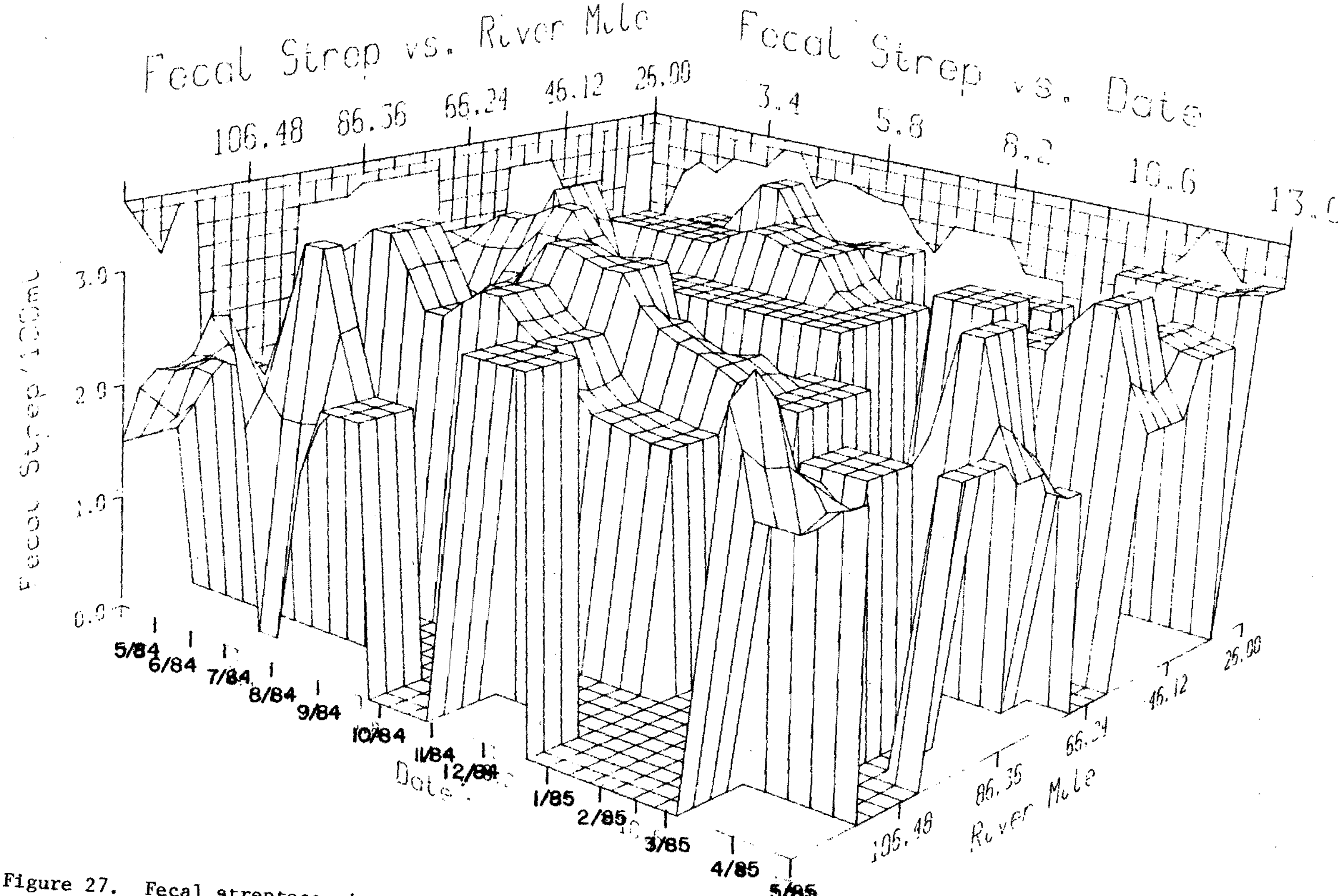


Figure 27. Fecal streptococci concentrations ($\log_{10}$) in Bear River samples taken monthly during the present study. River mileage is the same as in Figure 18.

Table 11. Values and dates of violations of microbiological standards for protection of beneficial uses of water, May 1984-May 1985 (see Table 2).

Station	TC value/date	FC value/date
Bear R. W. Fairview, ID [490610]		2200/7 Aug. 1984
Bear R. W. Richmond [490382]		5000/7 Aug. 1984
Bear R. bl. confl. w/Cub R. [490368]		4500/7 Aug. 1984
Bear R. ab. Cutler res. [490326]		2000/7 Aug. 1984
W. Side Canal [490195]		2000/7 Aug. 1984
Cub R. W. Franklin, ID [490379]		5300/7 Aug. 1984
Cub R. W. Richmond [490425]		3000/7 Aug. 1984
Logan R. ab. confl. w/L. Bear R. [490504]		2000/7 Aug. 1984
L. Bear R. W. Avon [490570]		2400/7 Aug. 1984
L. Bear ab. confl. w/Logan R. [490500]	7300/5 Sep. 1984	3500/7 Aug. 1984

37°C for 48 hours and 72 hours. The broth was streaked for isolation of suspect colonies on Hektoen Enteric and Xylose Lysine Desoxycholate agars. Bacterial colonies typical of Salmonella were tested for the biochemical characteristics of this group according to methods recommended by the American Public Health Association (APHA 1981). No Salmonella were found at any of the stations sampled.

Campylobacter jejuni isolation used the selective enrichment media of Wesley et al. (1983) and the confirmatory techniques recommended by Luechtefeld et al. (1981). Campylobacter jejuni was isolated from both the Cub River west of Richmond and from the Bear River at Amalga. The other sites did not yield this organism.

An attempt to quantify the concentration of Salmonella sp. and C. jejuni in samples taken October 6 at the same four sites using most probable number (MPN) techniques failed to yield positive results for either organism. This indicates that the October 6 samples contained less than one per liter of either of these pathogens.

Analyses for enteric viruses and pathogenic protozoans, especially Giardia lamblia, are needed, and should be included in a subsequent study.

RESERVOIR STUDIES

Oneida Reservoir

Although there are several mainstream reservoirs on the Bear River in Idaho and Utah, apparently none except Hyrum Reservoir have been studied in a more than prefunctory way. Oneida Reservoir was studied during the summer of 1984 to collect data that would be useful in calibrating the water quality model.

On May 20, 1984, Oneida Reservoir was very weakly stratified, and the 15.4°C inflow flowed under the warmer surface waters. Supersaturated oxygen concentrations in the surface 3 to 4 meters near the dam suggested a spring algal bloom.

On July 10 and August 7, 1984, there was no indication of thermal stratification at any sampling point along the length of the reservoir. There was measurable oxygen depletion below 11 meters nearest the dam on August 7. Apparently, Oneida Reservoir does not develop stable thermal stratification throughout the summer, but remains completely mixed and well oxygenated except for part of the deepest portion of the reservoir nearest the dam.

Cutler Reservoir

Cutler Reservoir is too shallow for more than transient thermal stratification to occur. Dissolved oxygen concentrations are probably near saturation throughout the water column during all seasons of the year. Suspended materials and the resulting turbidity change vary little from the entrance of the Bear River to the dam. Sampling done June 25, 1984, showed increased concentrations of coliform and fecal streptococci bacteria below the confluence of the Bear River, and these concentrations did not decrease as the reservoir flowed toward the dam.

Sampling done September 25, 1984, showed high numbers of fecal indicator bacteria in the southern shallow portions of the reservoir near the confluence of the Little Bear and Logan Rivers. These bacteria may be due to large flocks of waterfowl which inhabitated this area. The numbers of indicators decreased nearer the dam, either through dilution from the Bear River or from destruction in the relatively warm reservoir water.

Light extinction data were gathered in Cutler Reservoir May 8, 1985. The high turbidity of the water, especially below the Bear River influent, limits light penetration and algal production within the reservoir.

Cutler Reservoir is a complex body of water with extensive shallow marsh areas which interact with river water as it flows through the reservoir. In the physical sense, this reservoir behaves more like a large slow flowing river than a lake.

OTHER SPECIAL STUDIES

The Bear River below Cutler Reservoir

Essentially the only historical data on the water quality below Cutler Reservoir and above the Malad River confluence is from the single sampling station immediately below Cutler. A sampling station was added at Interstate Freeway 15 (I-15) near Honeyville with the inception of the present project, but no information is available on water quality between these points. To fill this information gap, intensive sampling of the Bear River between Cutler Reservoir and the I-15 bridge near Honeyville was conducted in August 1984. On August 15, selected points along the river, easily accessible by automobile, were sampled as well as the farthest north point on the West Side Canal. On August 31, the Bear River below Cutler Reservoir was floated, and samples were taken from the river and some obvious point inputs to the river. Sampling locations and the results of analysis of these samples are shown in Table 12. The August 15 sample from the Bear River at route 154 had extremely high numbers of fecal streptococci, a very high fecal streptococci to fecal coliform ratio (suggesting animal fecal material), an elevated conductivity, elevated total phosphorus and NaOH-P concentrations, and an elevated nitrate concentration. These data suggest a "slug" of Bear River water carrying animal waste at this location.

The August 15 sample of the Bear River at Petersen Park had only 82 $\mu g \cdot \ell^{-1}$ total phosphorus, but 76 percent of this phosphorus was NaOH extractable. Organic or fertilizer phosphorus may be the source of this labile phosphorus.

The Bear River at Garland Springs had an elevated concentration of nitrate on August 15. The relatively high concentration of nitrate in Garland Spring found in the August 31 sample suggests that the spring influences the nitrate concentration of the Bear River at this point.

On August 31, high concentrations of nitrate were observed in water entering the Bear River from a wash near Beaver Dam, in a spring near a farm adjacent to the river, and in a stream near Garland Springs and from Garland Springs. Construction activities were obvious on the wash near Beaver Dam, and may have contributed to the nitrate load of that small stream. Except for very localized effects, none of these inputs appreciably impact the nitrate concentration in the river. No major water quality problems were observed from the August 31 sampling.

Special Sampling of the Cub River

Graphical, cluster, and principal components analyses of the Bear River 208 data identified the Cub River as a probable source of bacterial and phosphorus pollution to the Bear River. In an initial attempt to locate points or river segments causing unusual changes in water quality, an intensive sampling of the Cub River was conducted July 25, 1984. The results of sample analyses are shown in Table 13. No major water quality problems were found. Temperature was observed to increase and dissolved oxygen (DO) decreased as the river flowed from Franklin, Idaho, to Richmond, but DO concentrations were always near saturation. The concentration of fecal streptococci in City

Table 12. Data from special sampling on the Bear River (BR) below Cutler Reservoir.

Station	Temp °C	pH	D.O. mg/l	Field Conductivity µmhos/cm	Total Phosphorus µg/l	NaOH-P µg/l	NaOP-P as % of TP	PO4-P µg/l	NO2-N µg/l	NO3-N mg/l	Total Coliforms #/100 ml	Fecal Coliforms #/100 ml	Fecal Streptocci #/100 ml	Clostridium perfringens #/100 ml
Sample Date: 15 Aug.														
BR below Cutler Res.	22	8.1	7.7	710	71	8	11	-	21	0.44	<500	400	540	9
BR @ Route 154 Crossing	21	7.9	6.9	870	168	47	28	-	18	0.67	1000	200	>10000	13
1500 Canal @ U.S. 191 Crossing	22	7.9	7.3	700	120	7	6	-	18	0.50	2000	530	1500	8
BR @ Garland Springs	21	7.7	7.2	710	134	15	11	-	10	1.00	500	200	3400	10
BR @ Petersen Park	24	7.8	7.2	650	82	62	76	-	15	0.54	<500	70	700	9
BR East of Elwood					132	7	5	-	16	0.48	1500	160	>400	7
BR @ I-15 Crossing near Honeyville	23	8.0	6.9	650	155	27	17	-	16	0.48	500	55	>400	14
Sample Date: 31 Aug.														
BR below Cutler Res.					179	13	7	100	12	0.42	<330	130	130	16
Beaver Dam Wash	14	-	-	850	86	15	17	59	9	5.11	2300	870	2500	49
BR @ 1st Farm	21.5	-	-	650	151	7	5	78	12	0.44	>330	800	1800	2
1st Farm Spring	14	-	-	750	87	9	10	66	3	2.19	3000	500	2000	19
Land Drain SW Collingston	14.5	-	-	355	66	7	11	30	6	0.55	2000	180	1000	12
Stream 1/2 mi. ab. Garland Springs	17	-	-	810	153	7	5	91	25	2.38	1300	100	430	3
BR ab. Garland Springs	20.5	-	-	770	212	9	4	112	8	0.49	670	33	270	16
Garland Spring	14	-	-	700	43	7	16	42	<2	2.35	<500	<16	<16	<1
BR @ Petersen Park	20	-	-	800	139	8	6	66	9	0.45	330	100	420	5
Flume below Elwood	20	-	-	550	135	8	6	67	8	0.67	1300	83	900	6

Table 13. Data from special sampling of the Cub River (CR), City Creek, and the Bear River, 25 July, 1984.

Station	Temp °C	pH	D.O. mg/l	Field Conductivity μmhos/cm	Total Phosphorus μg/l	NaOH-P μg/l	NaOH-P as % of TP	NO2-N μg/l	NO3-N mg/l	Fecal Streptococci #/100 ml
CR West of Franklin, ID.	16.5	8.2	9.0	340	127	9	7	2	0.29	320
CR East of Lewiston	17.5	8.1	7.3	340	114	9	8	7	0.54	420
CR West of Cove	20	7.9	7.1	350	135	8	6	6	0.57	740
CR N. W. of Richmond	21	7.9	7.7	370	181	11	6	6	0.68	400
CR W. of Richmond	21.5	7.5	7.6	395	118	17	14	10	0.75	580
City Creek below Impoundment	15	7.9	9.0	260	154	9	6	3	0.48	1900
CR below City Creek	20	7.9	7.5	390	340	22	6	11	0.74	960
CR above Bear River	19.5	7.9	7.6	380	118	19	16	11	0.73	440
Bear R. @ Route 170 above Cub River	23	7.9	7.4	750	72	8	11	4	0.51	600
Bear R. @ Amalga	26	8.1	9.2	700	76	16	20	4	0.49	1100

Creek was relatively high, suggesting increased fecal pollution of that stream, but the impact on the Cub River was only slight. Elevated concentrations of total phosphorus and NaOH-P were observed below City Creek, but the phosphorus concentration in City Creek does not seem to explain the increase. At the further downstream station above the confluence with the Bear River, total phosphorus concentration was similar to more upstream samples, but percent bioavailable P was higher. Total phosphorus concentration in the Cub was about twice the average concentration in the Bear River above and below the confluence with the Cub.

Monthly sampling data shows that high levels of total coliform bacteria still occur in the Cub River (Table 11), and elevated levels of ammonia and BOD were observed (Table 9). Sources of pollution to the Cub River need to be further elucidated so that management practices can be considered. Major point sources of industrial wastewater on the Cub River have been diverted to spray irrigation. Effluent from the Richmond City Wastewater Lagoons is entering the Cub River, and efforts are underway to improve the quality of that effluent by adding another lagoon cell and using intermittent sand filters to remove solids. Nonpoint sources of pollution probably present the greatest challenge to improve the quality of the Cub River.

Special Sampling of the Little Bear River

Unusually high numbers of *Clostridium perfringens* spores in monthly samples taken August 7 ($410 \cdot 100\ m\ell^{-1}$) and high numbers of total coliforms ($7300 \cdot 100\ m\ell^{-1}$) and *C. perfringens* ($130 \cdot 100\ m\ell^{-1}$) found September 5, 1984, from the Little Bear River above its confluence with the Logan River prompted a special round of sampling on the Little Bear River on September 12. The results from the analysis of these samples are shown in Table 14.

High numbers of total coliforms were found in the sample taken from the Little Bear River west of Paradise. A sample of runoff water entering the Little Bear River below Hyrum Reservoir was sampled and found to contain high numbers of total coliforms and fecal streptococci with lower numbers of fecal coliforms, suggesting animal waste. Fifty percent of total phosphorus was NaOH extractable as bioavailable phosphorus suggesting fertilizer phosphorus as a source. Other samples of the Little Bear River did not indicate serious pollution problems. The farthest downstream sample west of Pelican Pond was low in fecal indicator bacteria. This implies that the source of indicator bacteria was very near the sampling point above the confluence with the Logan River. Unfortunately a sample was not taken at that point during this special sampling. The wet lands near the confluence sampling point is heavily grazed by cattle, and the fecal indicators may come from this source. These results emphasize that inputs of indicator organisms to the Bear River and its tributaries may be very localized and intense resulting in high concentrations in portions of the streams. Again, most of the indicators appear to come from animal sources.

Sampling of Oxbows and Minor Tributaries

Table 15 presents results from samples taken August 21, 1984, from selected oxbow ponds, The Barrens marsh, Summit Creek, Logan City wastewater lagoons receiving stream, Logan Fish Hatchery Pond, and Hopkins Slough. Oxbows below the Cache Valley Cheese plant at Amalga, east of Cornish, east of Trenton, and west of Smithfield had water quality not especially different from the Bear River. The oxbows near Amalga, Cornish, and Trenton had slightly depressed dissolved oxygen concentrations, and those east of Trenton and west of Smithfield had higher total coliform and fecal streptococci concentrations, respectively. The oxbow

Table 14. Data from special sampling of the Little Bear River (LB) 12 September, 1984.

Station	Temp °C	pH	D.O. mg/l	Total Phosphorus µg/l	NaOH-P µg/l	NaOH-P as % of TP	PO4-P µg/l	NO2-N µg/l	NO3-N mg/l	Total Coliforms #/100 ml	Fecal Coliforms #/100 ml	Fecal Streptococci #/100 ml	Clostridium perfringens #/100 ml
LB Below Avon @ 10700 S.	15	8.2	9.1	38	<3	<8	23	7	0.36	500	420	570	2
LB W. Paradise @ 8700 S.	15	7.8	9.1	78	3	4	38	7	0.71	14000	500	1900	6
LB Below Hyrum Res. @ 2400 W.	18.5	7.8	8.5	30	<3	<10	6	19	0.86	500	33	250	2
Runoff Below Hyrum Res. @ 2400 W.	21.0	7.9	8.3	73	37	50	41	6	1.43	5000	450	3000	1
LB @ U.S. 89/91 Crossing	20	7.9	8.2	31	<3	-10	6	22	0.74	2000	130	420	1
LB W. of Pelican Pond	22.5	7.5	8.1	91	3	3	16	9	1.17	500	300	300	17

Table 15. Data from special sampling of selected Bear River oxbows, marshes, and minor tributaries 21 August, 1984.

Station	Temp °C	pH	D.O. mg/l	Field Conductivity µmhos/cm	Total Phosphorus µg/l	NaOH-P µg/l	NaOP-P as % of TP	PO4-P µg/l	NO2-N µg/l	NO3-N mg/l	Total Coliforms #/100 ml	Fecal Coliforms #/100 ml	Fecal Streptocci #/100 ml	Clostridium perfringens #/100 ml
The Barrens	18	8.8	4.7	8000	1007	127	13	-	3	0.27	<500	300	1000	41
Below Cache V. Cheese	19	8.0	6.4	850	183	15	8	-	24	0.10	<500	300	450	4
East of Cornish	20.5	8.2	6.7	790	94	15	16	-	10	0.69	1000	400	520	1
East of Trenton	18.5	8.2	6.4	810	107	7	7	-	35	0.57	3000	760	282	4
West of Smithfield	20.0	8.2	7.2	790	102	11	11	-	17	0.96	500	360	9000	1
Benson	25	8.3	9.8	750	155	13	8	-	26	0.12	13000	380	500	8
Summit Creek	16	8.1	8.6	630	58	19	32	-						
Farm Runoff to Hopkins Slough	25	7.6	7.1	750	63	13	21	-	25	0.56	15000	2800	7500	4
Logan Lagoon Receiving Stream @ Logan R.	22.5	7.8	7.1	720	105	11	10	-			2000	240	1000	13
Logan Fish Hatchery Pond	19.5	8.1	10.1	600	114	12	11	-	7	0.09	500	300	82	10
Hopkins Slough					85	20	24	-	15	2.74	9000	1000	1100	12

at Benson had supersaturated DO from algal and aquatic plant photosynthesis and extremely high numbers of total coliforms. This high level of total coliforms implies that there is an input of fecal material, probably from dairy farms adjacent to the oxbow.

A sample from the Barrens marsh was high in salinity (i.e., conductivity), total phosphorus, and bioavailable phosphorus. The large waterfowl population in this area probably contributes to fecal streptococci found in this sample. Further reconnaissance into the amount of brackish or saline and phosphorus rich water in the Barrens area and the possible impact on the water quality of the proposed Barrens Reservoir is recommended.

The high numbers of total and fecal coliforms and fecal streptococci in a sample of a small stream running through a farm lot into Hopkins Slough demonstrates the potential this kind of drainage has for fecal pollution of waterways. The low number of *Clostridium perfringens* spores in this sample casts some doubt on the usefulness of this indicator in detecting pollution from farm wastes. It is somewhat surprising that this sample shows relatively low concentrations of nitrate and phosphorus. Total phosphorus was 21 percent available.

Hopkins Slough had high numbers of indicator bacteria, a relatively high nitrate concentration, but moderate phosphorus concentrations. Again, the higher availability of the total phosphorus suggest organic or fertilizer phosphorus is important in this stream. The high availability of phosphorus in Summit Creek leads to a similar conclusion about the sources of phosphorus in that stream.

Samples of the Logan Fish hatchery pond and the Logan City wastewater lagoon receiving stream indicated that these waters were of relatively good quality.

Northern Bear River Phosphorus Loads

The extent of springtime phosphorus loading to the Bear River below Bear Lake and above the Utah-Idaho border was investigated on sampling trips taken March 26, April 23, and May 14, 1985. Areas of high erosion and agricultural land use that may be important in contributing phosphorus and sediment to the Bear River were identified with the assistance of local Soil Conservation Service personnel. The Weston Creek, Fivemile Creek, Deep Creek, and Battle Creek watersheds located near Preston, Idaho, were selected for closer study since they contain areas of land sliding and high erosion.

On March 26 samples were taken from the Bear River starting east of Cornish, Utah, and extending upstream to the Bear Lake Inlet Canal. Results of analyses of samples collected are shown in Table 16. Concentrations of total, ortho, and NaOH extractable phosphorus along the course of the Bear River are illustrated in Figure 28. Relatively small changes in total and orthophosphorus concentrations were observed along the approximately 100 miles of river from the Bear Lake Outlet Canal to below Oneida Reservoir at Riverdale, Idaho. However, between Riverdale and Cornish, Utah, a nearly fivefold increase in total phosphorus and a threefold increase in orthophosphorus were observed. In this river reach, Battle Creek, Deep Creek, Fivemile Creek, and Weston Creek all pass through areas of high soil erosion and empty into the Bear River. The high concentrations of phosphorus carried by these streams are shown in Table 16. In addition to tributary inputs, bank and bed erosion by the Bear River itself may contribute to the phosphorus load in this reach.

Suspended solids, total phosphorus, orthophosphorus, and NaOH phosphorus concentrations in Battle Creek, Deep Creek, Fivemile Creek, and Weston Creek on March 26, April 23, and May 14, 1985,

Table 16. Phosphorus and suspended solids concentrations in samples of the Bear River and selected tributaries taken March 26, 1985.

Sample Location	Approx. Flow (cfs)	Suspended Solids (mg/l)	Total Phosphorus (µg/l)	Ortho-Phosphorus (µg/l)	NaOH-Phosphorus (µg/l)	% NaOH of Total
Bear R. east of Cornish	-	190	238	33	18	7
Weston Creek	15	800	409	53	18	4
Fivemile Creek	3	600	1037	108	25	2
Deep Creek	20	1230	503	66	28	6
Battle Creek	10	3050	1704	144	36	2
Bear R. @ Riverdale	-	24	49	11	15	31
Bear R. abv. Oneida Res.	-	20	48	19	10	21
Bear R. @ Grace	-	14	30	11	9	29
Bear R. abv. Soda Point Res.	-	70	105	20	10	9
Bear R. @ Wooley's	-	60	51	16	9	18
Bear Lake Outlet Canal	-	74	108	21	12	11
Bear Lake Inlet Canal	-	140	293	60	11	4

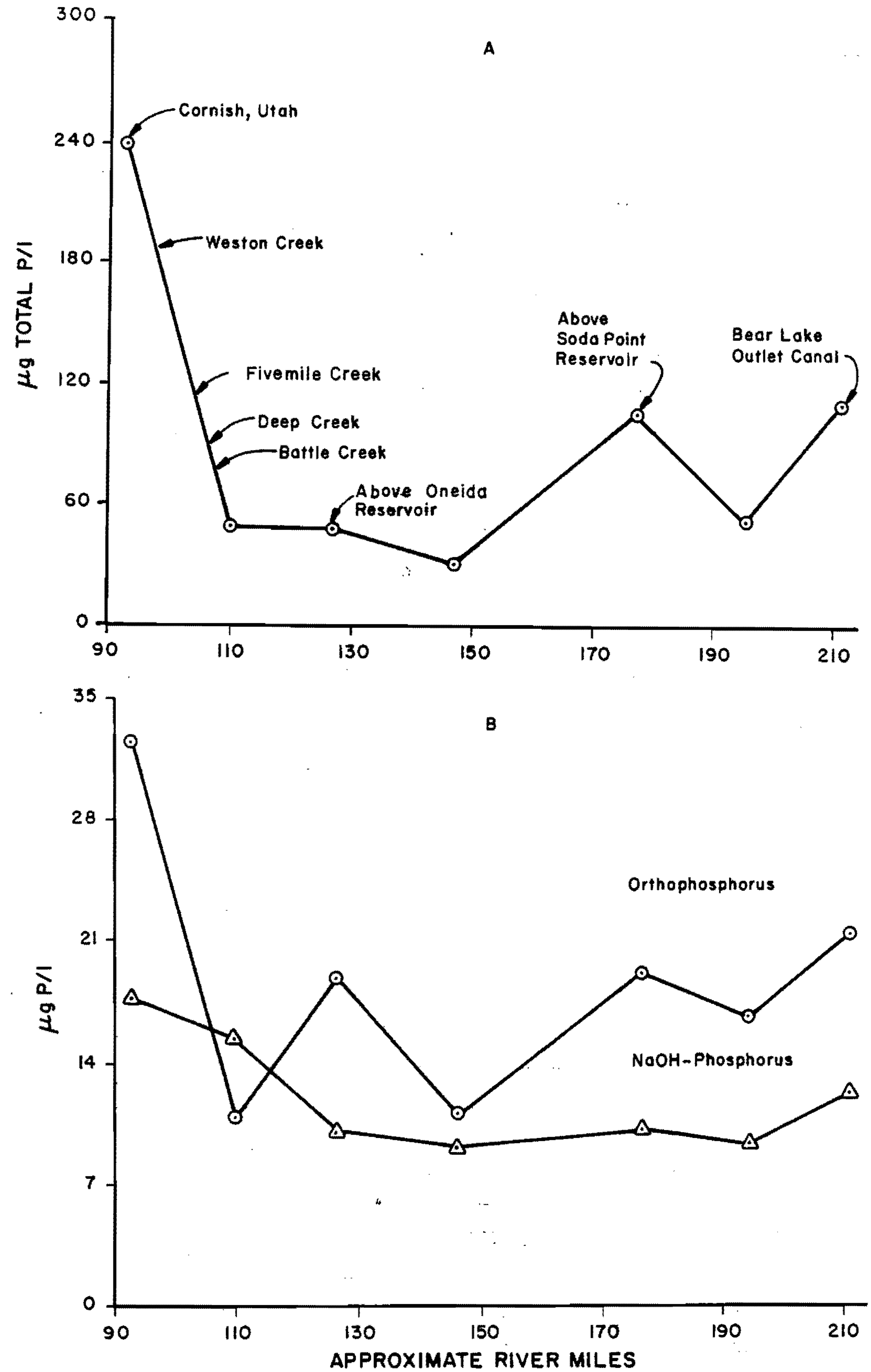


Figure 28. Phosphorus concentrations in the Bear River March 26, 1985. Part A shows total phosphorus, sampling locations, and confluence locations for phosphorus laden tributaries. Part B shows orthophosphorus and NaOH-phosphorus concentrations.

are illustrated in Figure 29. Loads of the three types of phosphorus decreased as the spring runoff diminished. It is noteworthy that the concentration of suspended solids in Fivemile Creek, Deep Creek, and Weston Creek increased in the May 14 samples, but none of the phosphorus types increased. This suggests that phosphorus bearing mineral materials in these watersheds may be weathered during cold season freeze-thaw cycles and move with snowmelt waters in the spring. Organic phosphorus may be mineralized and solubilized by accelerated decomposition activity during warmer spring weather and contribute to the orthophosphorus load in the spring runoff. In addition, buoyant organic particulate matter, relatively high in phosphorus, may be transported by spring runoff waters. Apparently, suspended material transported by these streams later in the spring are not rich in phosphorus content and increased flows caused by rainfall events may dilute the phosphorus load in spite of increased suspended solids concentrations (e.g., Deep Creek, May 14, Figure 29).

Further investigations of sources and magnitudes of inputs of phosphorus in the Bear River watershed are needed, but it appears that control of erosion and sources of phosphorus in the watersheds of the creeks discussed above will be important in decreasing the phosphorus concentration in Bear River water entering the proposed Amalga Reservoir.

Phosphorus Inputs to the Mill Creek and Avon Reservoirs

No water quality information was available on the Blacksmith Fork River and Mill Creek at the proposed Mill Creek Reservoir site or on the South Fork of the Little Bear River and Davenport Creek at the proposed Avon Reservoir site. Information about phosphorus and suspended solids inputs to these reservoirs was critical to eutrophication modeling efforts, so samples were taken and analyzed in the spring of 1985. The results of these analyses are listed in Table 17.

On April 9, Mill Creek carried very turbid, solids laden water that was high in total, ortho, and NaOH phosphorus. Blacksmith Fork contained relatively little suspended solids and phosphorus. One month later the suspended solids and phosphorus load of Mill Creek had diminished substantially, but the NaOH extractable fraction of the phosphorus load remained high. There were only slight changes in the phosphorus concentrations in the Blacksmith Fork at Anderson Ranch between the April and May samples.

The phosphorus concentrations in the two principal streams are considerably lower than in the Bear River or its tributaries lower in the watershed, but sufficient phosphorus may be available to generate algae blooms in portions of the reservoir during warm summer months (see eutrophication modeling section below).

The South Fork of the Little Bear River and Davenport Creek, the principal tributaries to the proposed Avon Reservoir, both contained elevated concentrations of suspended solids and phosphorus on April 9. Ortho and NaOH extractable phosphorus were 36 and 26 percent of the total phosphorus, respectively, implying that a relatively large fraction of the total phosphorus is biologically available.

Concentrations of total phosphorus decreased nearly threefold in the South Fork of the Little Bear River and Davenport Creek by the May 9 sampling. Ortho and NaOH extractable phosphorus decreased to concentrations that are not likely to support serious eutrophication problems. Phosphorus loading associated with early spring runoff appears to be the most serious threat to water quality of the Avon Reservoir.

Sedimentation

The settling characteristics of suspended solids, and the associated turbidity, in Bear River water may

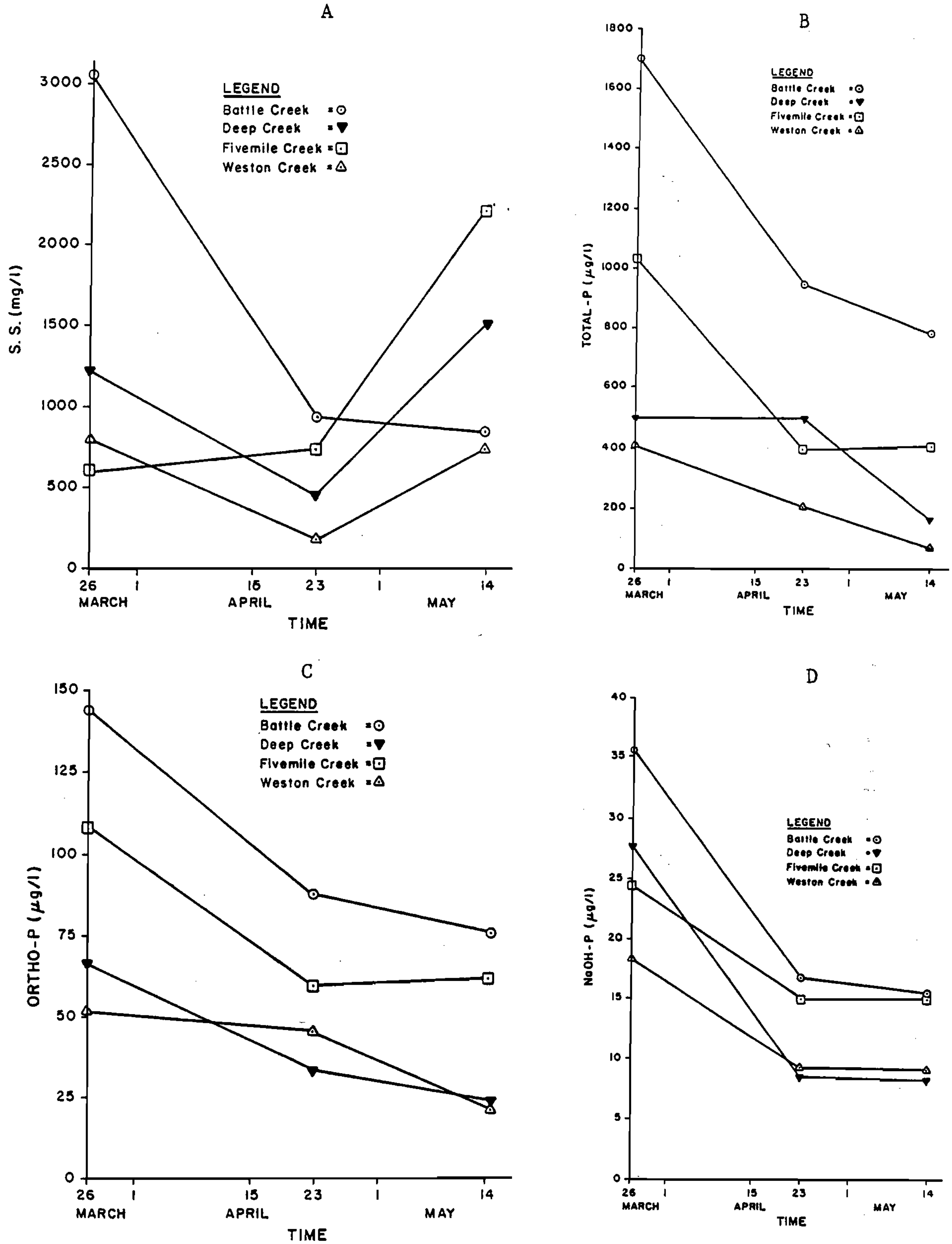


Figure 29. Concentrations of suspended solids (A), total phosphorus (B), orthophosphorus (C), and NaOH phosphorus (D) in tributaries to the Bear River in a high erosion area near Preston, Idaho.

Table 17. Phosphorus and suspended solids concentrations in streams at the proposed Mill Creek and Avon Reservoir sites.

Sample Location	Date	Approx. Flow (cfs)	Suspended Solids (mg/l)	Total Phosphorus (μg/l)	Ortho-Phosphorus (μg/l)	NaOH-Phosphorus (μg/l)
Mill Creek abv. Anderson Ranch	9 Apr 85	3	220	255	37	57
	9 May 85	1	10	37	16	14
Blacksmith Fork at Anderson Ranch	9 Apr 85	5	16	<10	<10	<10
	9 May 85	5	16	21	7	<7
Blacksmith Fork blw Anderson Ranch	9 Apr 85	10	71	101	35	14
	9 May 85	10	17	35	13	<7
S. Fork L. Bear R. at Forest Boundary	9 Apr 85	10	64	133	48	34
	9 May 85	5	9	45	14	11
Davenport Creek at Forest Boundary	9 Apr 85	15	110	161	46	26
	9 May 85	12	34	63	8	7

affect the treatment costs for water leaving the proposed Honeyville Reservoir and the light penetration within the reservoir. Increased light penetration increases the volume of water able to support algal growth and intensifies euthrophication.

Settling kinetics of the solids in a sample of Bear River water collected May 28, 1985, above Cutler Reservoir were studied using the procedures of Metcalf and Eddy, Inc. (1979). An 8 ft (2.4 m) by 0.5 ft (0.15 m) diameter transparent plastic column was filled with 11.75 gallons (44.5 liters) of river water. Samples were withdrawn at arbitrarily chosen intervals from sampling ports in the column at 2, 4, and 6 ft (0.6, 1.2, and 1.8 m) below the water surface and turbidity measurements were made. Differences of less than 10 percent removal were observed between the sampling ports. The turbidity removal over 48 h of settling is illustrated in Figure 30. Initial turbidity was 33 NTU and was reduced to 3 NTU, about 8 percent of the original value, after 48 h. Samples taken after 13 days of settling (data not shown) did not show an appreciable decrease in turbidity from that measured after 48 h.

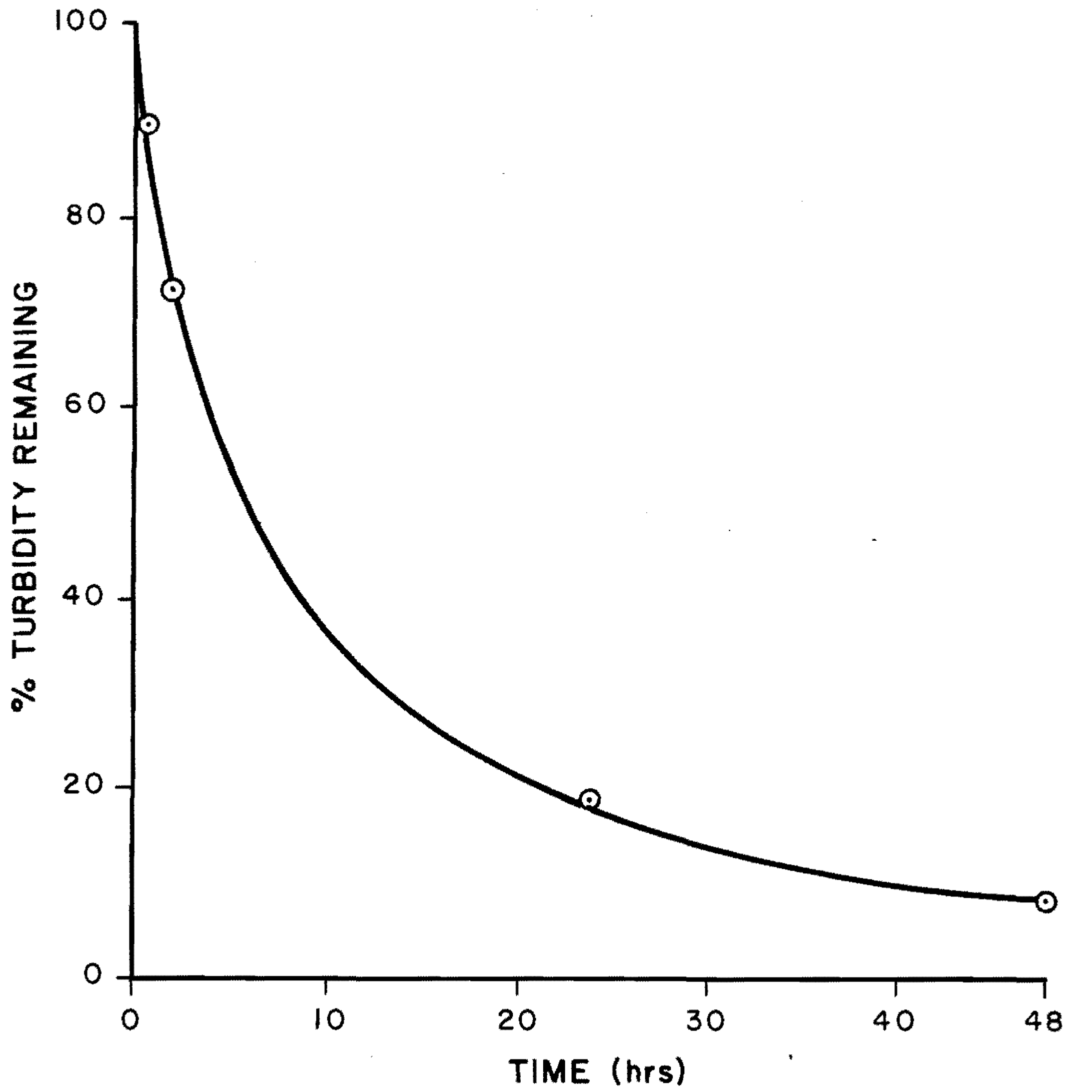


Figure 30. Turbidity settling kinetics in a sample of Bear River water.

Since the hydraulic residence time in the Honeyville Reservoir under high flow conditions is anticipated to be about 26 days, over 90 percent removal of river borne turbidity can be expected. The increased clarity of the water may decrease treatment costs, but increased algae production may increase turbidity, add to taste and odor problems, and increase trihalomethane precursor formation (Jones and Lee 1982a).

MODELING THE EUTROPHICATION POTENTIAL OF PROPOSED RESERVOIRS

Introduction

During the past decade water resources managers have become familiar with a wide variety of computer models for predicting water quality in rivers and impoundments. These models range in degree of sophistication from relatively simple lumped parameter regression equations to very complex multiparameter, two-dimensional (in rare cases three-dimensional), dynamic simulation models. The cost of applying a model increases rapidly with the degree of complexity; consequently, it is reasonable to select the lowest level of model complexity commensurate with the objectives of a particular study. Often a good strategy is to start with a low level screening model and gradually increase the complexity of subsequent models to address specific questions.

Reservoir eutrophication is one of the most difficult environmental parameters to model. It is manifested by excessive growths of planktonic (suspended) and attached algae, and aquatic macrophytes (water weeds) which can have deleterious effects on the beneficial uses of lakes and reservoirs. Excessive growths of aquatic plants can interfere with the use of waters for domestic and industrial supply, recreation, fisheries, and other beneficial uses. There may also be a significant relationship between the degree of eutrophication and the amount of trihalomethanes formed during chlorination of water during treatment for domestic use (Jones and Lee 1982a). Trihalomethanes are compounds which if ingested in large amounts are known to be carcinogenic to animals. Eutrophication can also cause deoxygenation of hypolimnetic (bottom) waters which can result in anoxic conditions and the generation of taste and odor problems as well as the release of excessive amounts of iron and manganese. MacKenthun and Kenp (1970) found that 62 percent of the water supplies from reservoirs that he studied had water quality problems associated with algae. Symons et al. (1971) found that 21 percent of the water supplies from reservoirs that they studied had taste and odor problems as well as problems with iron, manganese, and sulfides where anoxic conditions existed.

The most cost-effective approach towards eutrophication management is usually to eliminate or reduce the cause of excessive aquatic plant growths. Algae and other aquatic plants need a wide variety of chemical constituents, in addition to sunlight, for growth. Usually, all constituents needed for optimal growth are present in surplus amounts, except for nitrogen and/or phosphorus. Phosphorus has been found most often to be the limiting nutrient. Not all suspended or dissolved phosphorus in a stream, lake, or reservoir is available for uptake and utilization by algae, and only that fraction of the total phosphorus which is bioavailable will affect algal growth (Williams et al. 1980). Fertilizer and organic forms of phosphorus tend to be more bioavailable than natural mineral (apatite) forms. Methods to control phosphorus loading from domestic wastewaters are readily available and relatively inexpensive to implement. Even in waterbodies in which algal growth is limited by nitrogen or some other factor, phosphorus load reduction can result in improved water quality if the phosphorus load reduction is sufficiently large to drive the waterbody to phosphorus limitation, and then reduced sufficiently beyond that to decrease algal growth. Because of the important linkages between phosphorus and eutrophication most practical models emphasize phosphorus related phenomena.

The three types of models which were used for the assessment of eutrophication potential in the proposed Honeyville, Amalga, High Oneida, Mill Creek and Avon Reservoirs are described in this section. A dynamic water temperature model (Caupp and Grenney 1982) was used to predict the degree of thermal stratification for the proposed reservoirs. Empirical trophic state models (Messer, Grenney, and Ho 1982, and Jones and Lee 1982b) were used to predict four average summer characteristics for the reservoirs: 1) waterbody phosphorus concentration, 2) chlorophyll concentrations, 3) Secchi depths, and 4) hypolimnetic oxygen depletion rates. RESEN, a longitudinal finite-difference simulation model, was applied to the reservoirs to assess seasonal peak algal concentrations and deoxygenation rates (Grenney, Messer and Ho 1981). In addition, standard reservoir trap efficiency curves (ASCE 1977) were used to estimate the fraction of suspended sediment that could be expected to pass through the reservoirs.

Water Temperature Model

The temperature model in this study is similar to other state-of-the-art temperature models now in use (HEC 1978, EPA 1978, and Grenney and Kraszewski 1981), but this model is structured to require less extensive input data. The reservoir is divided into horizontal slices (Figure 31) and each slice is assumed to be completely mixed. Flows entering the reservoir sink to the layers of equal density. If the density of the inflow is outside the range of densities within the reservoir, the entry is established at either the surface or the bottom. Once the entry level is determined the inflow is distributed in the convectively mixed zone (Krenkel and Novotny 1980). Withdrawal may flow over the spillway or through as many as 10 ports located at different elevations in the dam. Local velocities associated with the flows are distributed within the withdrawal zone (Krenkel and Novotny 1980). Heat is distributed vertically throughout the reservoir by advection and dispersion. The heat flux at the surface is represented by the heat budget equation:

$$H = H_a + H_s - H_{br} - H_e + H_c \qquad (1)$$

where

- H = net surface heat flux (Kcal/m^2/day),
- H_s = short wave radiation entering the water (Kcal/m^2/day),
- H_a = incoming longwave radiation from the atmosphere entering the water (Kcal/m^2/day),
- H_{br} = back radiation emitted by the water (Kcal/m^2/day),
- H_e = energy utilized by evaporation (Kcal/m^2/day), and
- H_c = energy conducted between the air and the water at the surface (Kcal/m^2/day).

The interelement transport of mass and conservation of heat is represented by the following partial differential equation:

$$V \frac{\partial T}{\partial t} = -\Delta z Q_z \frac{\partial T}{\partial z} + \Delta z A_z D_z \frac{\partial^2 T}{\partial z^2} + Q_i T_i - Q_o T + \frac{A_h H}{\rho c} - T \frac{\partial V}{\partial t} \qquad (2)$$

where

- T = temperature in degrees Celsius

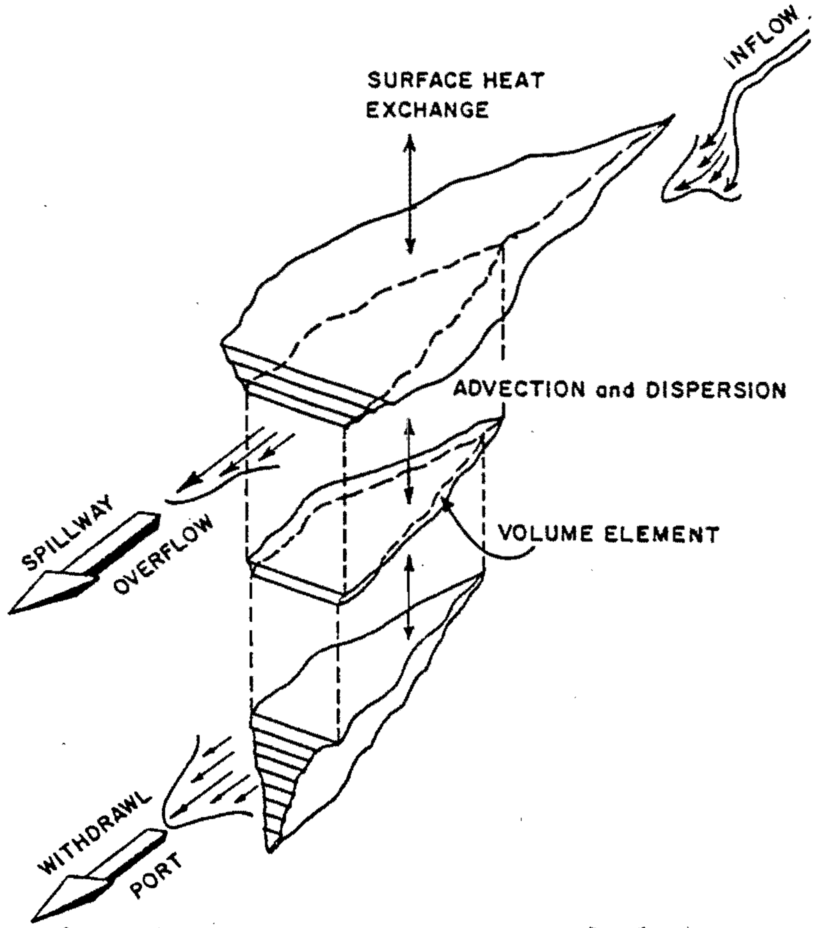


Figure 31. Schematic diagram of reservoir configuration.

V = volume of the fluid element in m^3

t = time in seconds

z = space coordinate in meters (vertical for the reservoir and horizontal for the stream)

Q_z = interelement flow in m^3/sec

A_z = element surface area normal to the direction of flow in m^2

D_z = effective diffusion coefficient in m^2/sec

Q_i = lateral inflow in m^3/sec

T_i = inflow water temperature in degrees Celsius

Q_o = lateral outflow in m^3/sec

A_h = element surface area in m^2

H = external heat sources and sinks in Kcal/m^2/sec

ρ = water density in kg/m^3

c = specific heat of water in Kcal/kg/°C

An implicit numerical method is used to find the solution to the above partial differential equation.

One disadvantage of most temperature models is the extensive meteorological data base required to run the model. This model avoids that difficulty by superimposing typical short term variations (3 hours) on long term trends (week, month, etc.). Daily data were obtained and evaluated for March through August over a 4-year period. Average monthly trends and typical diurnal variations were calculated. For example, the average daily air temperature trend is assumed to either increase or decrease linearly over a month. The air temperatures at the end and beginning of the period are entered and average daily values are obtained by linear interpolation. Three-hour variation about the mean at the daily level are handled by using a typical temperature distribution function. This relationship was obtained by plotting the instantaneous distribution of temperature over the day. A sample distribution is shown in Figure 32. The length of time covered by each input period is dependent upon data availability and uniformity. A 1-month period was selected for this study.

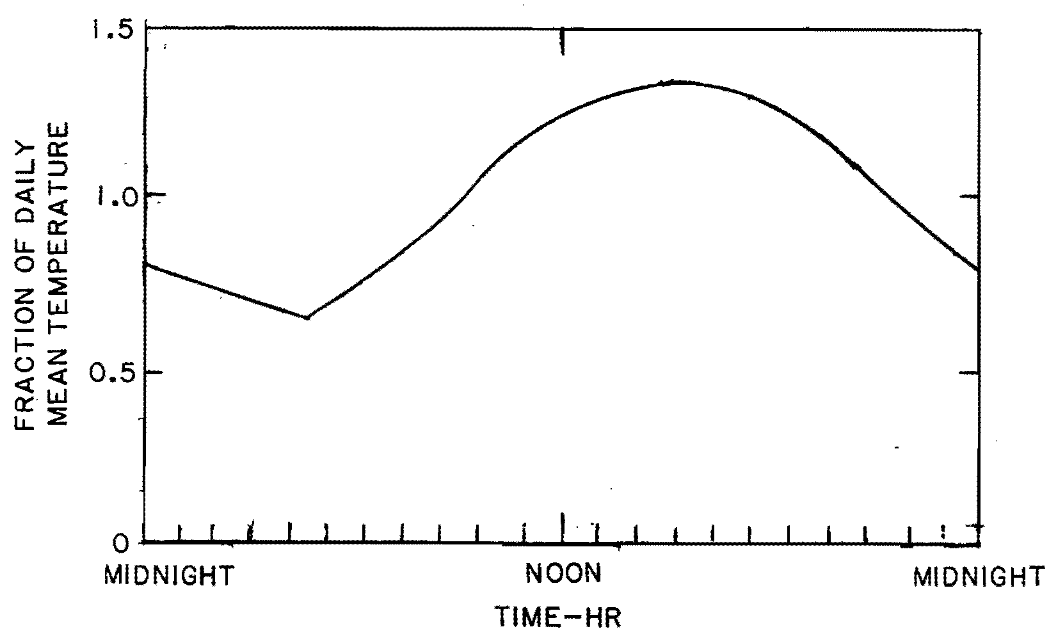
Empirical Trophic State Model

Phosphorus Concentration Models

The purpose of all I/O trophic state models is first to predict the phosphorus concentration in the lake water as a function of phosphorus and hydraulic loadings, and subsequently to infer the resulting water quality based on the conversion efficiency of the phosphorus to algal biomass. All of the models employ a mass balance of phosphorus in the lake water column to predict a steady state phosphorus concentration. The general equation is:

$$\frac{d(P)_L}{dt} = \Sigma Q_{in}\ (P)_{in} - Q_{out}\ (P)_L - \sigma\ (P)_L \qquad (3)$$

where $[P]_{in}$ and $[P]_L$ refer to mean annual phosphorus concentrations in the lake inputs and water column, respectively, Q_{in} and Q_{out} are the mean annual hydraulic inputs and outputs (usually assumed to be equal, and σ is a sedimentation "constant." In actuality, however, the sedimentation term is not a



TYPICAL AIR TEMPERATURE DISTRIBUTION

Figure 32. Sample relationship used to calculate instantaneous meteorological value from mean daily value.

constant, but represents a complex function of internal phosphorus sources and sinks, including types and concentrations of phosphorus in lake inputs, lake hydrology and morphometry, sediment chemistry, and oxygen content of the water in contact with the sediments. A value for the sedimentation term can be calculated by difference if existing lake input-output data are available (Dillon and Rigler 1974), but it must be determined empirically as a function of lake morphometry and hydrology (Reckhow 1979) for a proposed reservoir.

In order to parameterize empirical models Equation 3 is set equal to zero, thus assuming steady state conditions, and solved for $[P]_L$ in terms of variables relating to phosphorus and hydraulic loading and mean lake depth. Table 18 summarizes the computational forms of the more popular predictive models. The Vollenweider 1975 model employed an empirical estimation of σ based on mean depth while the 1976 version related to the hydraulic residence time, τ. The Larson and Mercier, Jones and Bachman, Reckhow, and Mueller models all represent attempts to parameterize the Vollenweider-type models using various data bases on lakes and reservoirs throughout the U.S. The Larson and Mercier and the Dillon and Rigler models require a retention coefficient, R, that must be estimated using the empirical Kirchner and Dillon (1975) approximation based on hydraulic loading. It is particularly important to note that although Equation 3 represents a <u>rational</u> mass balance on phosphorus, these models have a strong <u>empirical</u> dependence upon the data base used to parameterize σ.

The relationship between the predicted steady state phosphorus concentrations and water quality depends upon the efficiency with which the algae comprising the phytoplankton of the lake convert phosphorus into cell biomass and/or chlorophyll. Biomass may be the more useful variable if the water quality parameters of interest are tastes and odors or filtering efficiency in water treatment plants, while chlorophyll may be more useful if the transparency of a recreational lake is the principal concern. Early models (e.g., Vollenweider 1975) employed an observation by Sawyer (1947) that average springtime phosphorus concentrations exceeding 20 mg $P \cdot m^{-3}$ resulted in algal problems in Wisconsin lakes. Subsequent refinements (e.g., Vollenweider 1976, Rast and Lee 1978) related empirical observations of mean annual (or summertime) chlorophyll <u>a</u> concentrations to predicted steady state phosphorus concentrations for the particular group of lakes being studied.

The empirical trophic state models described here have provided the basis for most eutrophication management programs during at least the past decade, and for good reason; they have proved remarkably robust. This property is somewhat puzzling in light of the seemingly endless number of factors that affect the sedimentation coefficient, σ, and the conversion efficiency of phosphorus to chlorophyll. The empirical nature of the former has already been noted; the latter depends on light, temperature, and other nutrients, and is species specific (Kalff and Knoechel 1978). Furthermore, Smith and Shapiro (1981) have shown that linear models relating chlorophyll <u>a</u> to phosphorus during the summer growing season have different slopes and intercepts in different lakes, despite the fact that a good fit was found for each lake. Nonetheless, all of the models in Table 18, except the Mueller model, have been successfully applied to large sets of lakes different than the original data set upon which they were based (Rast and Lee 1978, Reckhow 1979).

<u>Empirical Chlorophyll Concentration Model</u>

The Organization for Economic Cooperation and Development (OECD) Eutrophication Study was undertaken to quantitatively define the relationship

Table 18. Empirical I/O models used to predict phosphorus concentrations in lakes.

Vollenweider (1975)	$[P] = \frac{1}{10 + z/\tau}$
Larson and Mercier (1976)	$[P] = \frac{L\tau}{Z}(1-R_p)$
	$R_p = \frac{1}{(1 + 1/\tau)}$
Jones and Bachman (1976)	$[P] = \frac{0.84}{z(0.65 + 1/\tau)}$
Kirchner and Dillon (1975)	$[P] = \frac{L\tau}{z}(1-R_p)$
	$R_p = 0.426 \exp(-0.271\ z/\tau)$
	$+ 0.574 \exp(-0.00949\ z/\tau)$
Vollenweider (1976)	$[P] = \frac{L/q_s}{(1 + \tau)}$
Mueller (1982)	$[P] = \frac{L/q_s}{(1+2.09\ \tau^{0.832})}$

$[P]$ = Steady state total phosphorus concentration (mg P/m^3)
L = Phosphorus loading rate (mg P/m^2-yr)
z = Mean depth (m)
τ = Hydraulic residence time (yr) = z/q_s
q_s = Surface hydraulic loading (m/yr)
R_p = Phosphorus retention coefficient (dimensionless)

between the nutrient (phosphorus) load to a waterbody and the eutrophication-related water quality response of the waterbody to that load. The 5-year study involved the examination of P load and response characteristics of about 200 waterbodies in 22 countries in Western Europe, North America, Japan, and Australia. Thirty-four of these waterbodies were located in the United States. Rast and Lee (1978) regressed the epilimnetic chlorophyll concentration against the phosphorus concentration for the OECD North American lake data set.

Jones and Lee (1982b) used data from 80 U.S. waterbodies to determine the P load-chlorophyll, P load-Secchi depth, and P load-hypolimnetic oxygen depletion rate relationships. The lines of best fit and the 95 percent confidence intervals for these data are shown in Figures 33A through 33C. The chlorophyll versus phosphorus loading relationship obtained by Jones and Lee (1982b) (Figure 33A) is not significantly different from the relationship obtained by Rast and Lee (1978). The normalized annual areal phosphorus loading (λ) is defined by:

$$\lambda = (L/q_s)/(1 + \sqrt{\tau_w}) \qquad (4)$$

where

L is areal annual phosphorus load (mg P/m^2/yr)

q_s is surface hydraulic loading (m/y)

$$q_s = Z/\tau_w$$

Z is mean depth (m)

τ_w is hydraulic residence time (yr)

A limnological classification of trophic states of lakes and reservoirs was developed by Jones and Lee (1982b) and is shown in Table 19. Lee et al. (1981) discuss how Table 19 and the empirical trophic modeling approach should be used in conjunction with desired beneficial waterbody uses, for water quality management. They stress that for most applications, planktonic algal chlorophyll concentration tends to be the most reliable eutrophication-related water quality indicator for those waterbodies having average amounts of inorganic turbidity and color. Secchi depth is an adequate secondary parameter.

RESEN, A Simulation Model for Riverine Reservoirs

RESEN is a mathematical model designed to simulate phytoplankton growth in small, riverine reservoirs. It is a linked box model with no dispersion, and is thus most suitable for relatively long, narrow reservoirs in which the concentrations of the constituents (nutrients, algae, etc.) vary as a function of time and downstream distance along the reservoir. At present, the model may only be applied under hydraulic conditions of either complete vertical mixing (one vertical compartment) or strong vertical stratification (two vertical compartments).

The model simulates the following state variables (water quality parameters):

1. Two or more types of phytoplankton (SNP_i)

2. Zooplankton (ZOO)

3. Available nitrogen (NA)

4. Available phosphorus (NP)

5. Biochemical oxygen demand (BOD)

6. Dissolved oxygen (DO)

The model was designed to incorporate functions representing the most significant mechanisms thought to influence phytoplankton growth dynamics

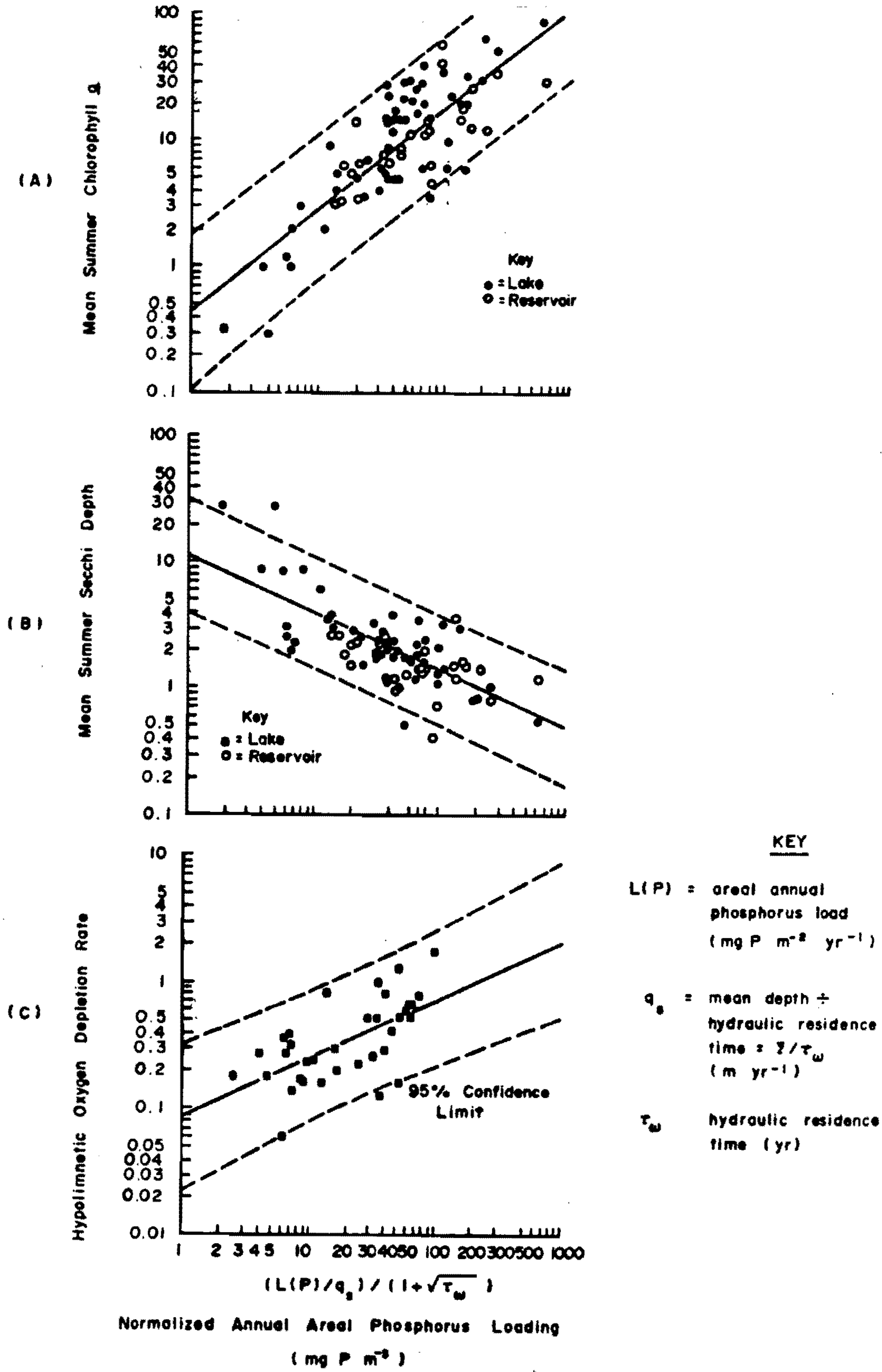


Figure 33. Updated P load-eutrophication related water quality response relationships for U.S. waterbodies. (From Jones and Lee 1982. Used with permission of Pergamon Press, Inc.)

Table 19. Limnological classification of trophic status of lakes and reservoirs (Jones and Lee 1982b).

Classification	Average Planktonic Algal Chlorophyll ($\mu g\ l^{-1}$)	Average Secchi Depth (m)	Average in Lake Total Phosphorus ($\mu g\ l^{-1}$)
Oligotrophic	<2.0	>4.6	<7.9
Oligotrophic-mesotrophic	2.1-2.9	4.5-3.8	8-11
Mesotrophic	3.0-6.9	3.7-2.4	12-27
Mesotrophic-eutrophic	7.0-9.9	2.3-1.8	28-39
Eutrophic	≥10	≤1.7	≥40

in turbid, fresh water environments. These include:

1. Phosphorus and nitrogen limitation of nutrient uptake;

2. Competition between types of phytoplankton for nitrogen and phosphorus;

3. Luxury uptake and nutrient storage in intracellular pools;

4. Phosphorus and nitrogen limitation of growth based on the intracellular nutrient pools;

5. Nitrogen fixation by cyanophyta;

6. Light limitation of growth, as influenced by suspended sediment and the self-shading effects of the phytoplankton;

7. Sensitivity of metabolic rates to temperature;

8. Selective grazing by zooplankton;

9. Sinking of phytoplankton;

10. Mineralization of nutrients from decaying phytoplankton and bottom deposits;

11. Depth of mixed zone.

The fundamental set of differential equations represent phytoplankton, nutrient, and oxygen dynamics. The equations are simplified by assuming that coefficients and boundary conditions are constant over time and allowing the system to approach equilibrium. Thus the results from the model show the conditions that would occur along the length of the reservoir if the boundary conditions were held constant for a sufficient period of time (approximately equal to the residence time of the reservoir). Messer, Grenney, and Ho (1982) have provided a detailed description of the model.

Interpretation of RESEN's Results

Interpretation of RESEN's results should be limited to estimating total chlorophyll concentrations. Insufficient input data, such as model growth parameters, nutrient availability (for nutrients other than phosphorus), and zooplankton parameters (grazing and growth coefficients) are available to model concentration of individual algal species. Growth parameters for algal species that are not at the extreme (some species grow best at extreme temperatures for example) were chosen. The results of RESEN can be used to estimate chlorophyll concentrations.

Insufficient data for calibration of zooplankton growth coefficients were handled by running RESEN for two cases. In case one zooplankton were allowed to increase and graze the preferred algal species to extinction. The inclusion of zooplankton growth would reduce maximum chlorophyll concentrations by removing phosphorus contained in engested algal cells. In the second case no zooplankton growth was permitted, allowing the species preferred by the zooplankton to increase to maximum levels. Actual chlorophyll concentrations are expected to fall between these two extreme cases.

Before results of RESEN could be used to model conditions at the algal species level, additional data would be needed on zooplankton grazing rates, release of phosphorus by zooplankton, zooplankton growth rates, etc., for algal species found in Hyrum.

Results from RESEN represent the chlorophyll concentration averaged over the depth of the mixed zone. RESEN calculates the average chlorophyll concentration by averaging the depth varying growth parameter (light extinction) over the mixed depth of the reservoir. RESEN does not calculate the maximum chlorophyll which can occur a few centimeters or meters of the reservoir's surface.

Table 19 shows chlorophyll concentrations associated with trophic conditions. Chlorophyll concentrations above 10 $mg \cdot m^{-3}$ are considered to indicate eutrophic conditions.

Extinction Coefficient

Light is absorbed and scattered in water, and decreasing light energy becomes available for algal photosynthesis and growth with increasing depth. The decreasing light intensity with depth can be expressed:

$$I = I_0 \, e^{-kd} \qquad (5)$$

where I is the intensity at a given depth, I_0 is the intensity at the water surface, k is the empirically determined extinction coefficient and d is the depth. Turbidity of the water which causes scattering of light is a major controlling factor of the extinction coefficient. Dissolved color may also be important, but is not likely to be a factor in Bear River system waters. As suspended particles settle out of the water in reservoirs the turbidity is decreased, light penetration increases, the extinction coefficient decreases, and more water volume becomes available to suggest algal growth.

RESEN was designed to handle two distinct cases with respect to light penetration. In case I the extinction coefficient is treated as a constant over the length of the reservoir. This assumption is suitable for most reservoirs with low to moderate extinction coefficients (extinction coefficient less than 1.5 per meter). In case II the extinction coefficient is assumed to decrease over the length of the reservoir. This case is used to model cases of reservoirs with extremely turbid incoming water where the extinction coefficient of the incoming water can be greater than 3.5 1/meter and decrease to less than 2.0 1/meter when the water reaches the dam. The decrease in extinction coefficient is due to suspended material settling out in the calm water of the reservoir. The decrease in extinction coefficient is a complex function of resident time, depth, particle size, and mixing conditions. RESEN approximates this complex function by the following equation:

$$E' = ext*e^{Kx} \qquad (6)$$

where

ext = initial extinction coefficient

x = distance in meters measured from headwater of reservoir

K = rate of decrease of extinction coefficient

E' = extinction coefficient x meters downstream of reservoir headwaters

The parameters are determined from field observations of similar reservoirs.

Observed Extinction Coefficient at Cutler and Oneida Reservoirs

Based on observations at Cutler and Oneida Reservoirs along with results from suspended sediment analyses, a rough estimate was made of the changes in the extinction coefficients with distance along the reservoir. Observations were made at Cutler to estimate whether or not the suspended material carried by the Bear River would remain suspended in the shallow reservoir. For comparison, observations were made at Oneida to estimate to what extent the suspended material would settle out and increase light penetration in a deeper reservoir.

Results shown in Table 20 for the May 8, 1985, sampling trip to Cutler Reservoir indicate turbidity remains high throughout the length of the reservoir. On the sampling trip of May 8, 1985, light extinction (as represented by extinction coefficient) was found to be extremely high (average value 4.9 $meter^{-1}$) and did not significantly change from the bridge north of Benson downstream toward the dam. Usually in reservoirs, the extinction coefficient decreases as suspended sediments settle out, but in Cutler Reservoir a combination of factors keep the material suspended. Laboratory settling tests on Bear River water indicated that the suspended material was extremely fine and would remain in suspension if the slightest current occurred in the settling column. Cutler Reservoir is shallow, often less than 2 feet, and in this shallow water, wind and water currents can keep the suspended material in suspension and resuspend material which has previously settled to the bottom.

Results from the sampling trip to Oneida Reservoir indicated suspended material carried by the Bear River at Oneida did settle out with a subsequent increase in light penetration. Results of the May 16, 1985, sampling trip are shown in Table 21.

The extinction coefficient at a given point can be approximated by:

$$ext_P = ext_I \, e^{-6x10^{-5} \, X}$$

where

ext_I = the initial extinction coefficient where the stream enters the reservoir

X = distance in meters from the headwaters of the reservoir

Suspended Sediment

The proportion of sediment passing through a reservoir will depend primarily on the average velocity of flow through the pool and the character of the sediment. Two methods were used to estimate the trapping efficiency of the proposed reservoirs for this study: 1) Brune's curve and 2) Churchill's curve (ASCE 1977). Brune's curve relates reservoir trapping efficiency to the ratio between reservoir capacity and mean annual water inflow (both in acre-feet). Churchill's curve relates reservoir trapping efficiency to the sediment index of the reservoir; where the sediment index is the retention time divided by the average cross-sectional velocity.

Table 20. Measured extinction coefficient along Cutler Reservoir.

Distance Upstream from Dam (miles)	Extinction Coefficient (m^{-1})
1 1/2	6.4
2 1/3	5.8
3 (Bear River branch)	4.6
3 (Logan River branch)	4.4
3 1/2 (Logan River branch)	3.9

Table 21. Variation of extinction coefficient along length of Oneida Reservoir.

Distance Upreservoir from Dam (miles)	Extinction Coefficient (m^{-1})
0.1	1.4
5	2.2
6	2.4
7	2.8

MODELING RESULTS

Introduction

Eutrophication is one of the major causes of water quality deterioration in reservoirs. When a eutrophic reservoir is used as the source for domestic water supply, numerous problems may be encountered associated with undesirable taste and odor, excessive iron and manganese concentrations, release of sulfides, reduced filter runs, increased chlorine demand, and sometimes increased trihalomethane (THM) precursor content (Jones and Lee 1982a).

The purpose of this study was to estimate the eutrophication potential of the proposed Honeyville, Amalga, Avon, Mill Creek, and Low Oneida Reservoirs and to draw some conclusions regarding their suitabilities as sources of raw water for domestic water supply. Also, the models are applied to the proposed Amalga, Avon, Mill Creek, and Low Oneida Reservoirs to estimate water quality conditions in these reservoirs and their impact on downstream water quality. Specifically, would any of these reservoirs improve conditions at Honeyville by trapping nutrients?

Three types of models were used to assess eutrophication potential. A dynamic water temperature model (Caupp and Grenney 1980) was used to predict the degree of thermal stratification. Empirical trophic state models (Messer, Grenney, and Ho 1982, and Jones and Lee 1982b) were used to predict four average summer characteristics for the reservoirs: 1) waterbody phosphorus concentrations, 2) chlorophyll concentrations, 3) Secchi depths, and 4) hypolimnetic oxygen depletion rates. RESEN, a longitudinal finite-difference simulation model, was applied to the reservoirs to assess seasonal peak algal concentrations and deoxygenation rates (Grenney, Messer, and Ho 1981).

The models were applied to Hyrum Reservoir and Cutler Reservoir before being used to estimate expected characteristics for the proposed reservoirs. The results from the Hyrum application were compared to observed data (Drury 1975) in order to obtain a "feel" for the accuracy of model application in this area.

Hyrum Reservoir Application

Hyrum Reservoir, Figure 34, is about 2 miles long and has an average depth of about 39 feet. The reservoir tends to increasingly stratify from May to September and significant algal blooms are observed in late summer and fall. Average annual inflow (35 year average) is 2.0 x 10^9 $ft^3 \cdot y^{-1}$ (64,120 $AF \cdot y^{-1}$). Drury (1975) measured 28 parameters in Hyrum Reservoir during the period May 26, 1972, to March 19, 1974, including phosphorus, chlorophyll, and temperature profiles. The reservoir experienced higher than normal flow regimes during the two years. The average inflow for water year 1972 was 4.45 x 10^9 $ft^3 \cdot y^{-1}$ (102,200 $AF \cdot y^{-1}$) which was 60 percent above normal. The average inflow for water year 1973 was 3.69 x10^9 $ft^3 \cdot y^{-1}$ (84,740 $AF \cdot y^{-1}$), which was 32 percent above normal. During the period June 1, 1973, to October 15, 1973, Drury used a compressed air diffuser to artificially destratify the reservoir.

Water Temperature Model

The temperature model was applied using inflows recorded for the Little

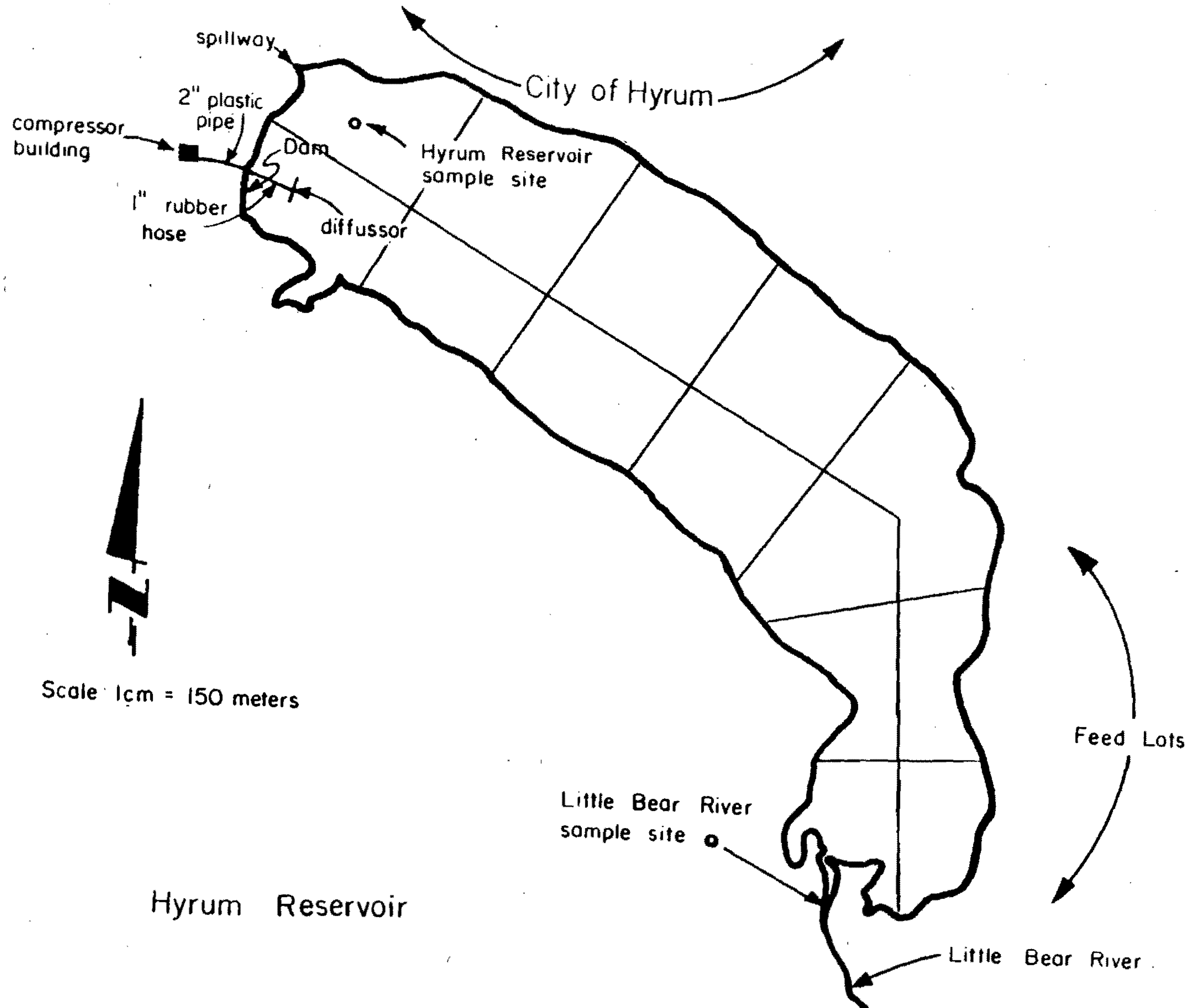


Figure 34. Map of Hyrum Reservoir showing sample sites and transects.

Bear River (USGS station 10106000) between April and October 1972. Meteorological data were the same as those estimated for the Amalga assessment (Appendix D). Table 22 shows the comparison between observed data and model results, and Figure 35 shows the results graphically.

The model adequately simulates the warming of the surface water for summer and fall. The simulated surface water temperatures do not warm as rapidly as the observed during the spring, but the difference is not more than 1 1/2°C (except for a short time in May). The simulated hypolimnion temperatures are close to observed except for July when the model is cooler. The writers think that the model should be improved to account for higher mixing in the hypolimnion caused by the relatively cool inflow entering at a greater depth. The depth of the thermocline is simulated well, the maximum gradient in July occurred at the same depth for both simulated and observed. Improved hypolimnetic mixing in the model would improve the correspondence of the simulated and improved temperature profiles.

In summary, the model does a reasonable job of simulating the spring-summer-fall temperature regimes in Hyrum Reservoir, but has a tendency to predict a stronger thermocline than actually occurs.

Empirical Trophic State Model

The empirical trophic state models were applied to Hyrum Reservoir for two conditions as shown in Table 23. Model case 1 represents water year 1972 with an estimated phosphorus loading of 9970 mg $P \cdot m^{-2} \cdot y^{-1}$. Model case 2 is similar except uses a higher loading rate (11,180 mg $P \cdot m^{-2} \cdot y^{-1}$) and a smaller reservoir volume (30 percent reduction) to represent late summer drawdown. Tables 24 and 25 summarize flow and water quality data for the Logan and Little Bear Rivers, respectively.

Predicted average waterbody phosphorus concentrations range from 102 to 136 $mg \cdot m^{-3}$ and are not significantly different for the two conditions. Using Figure 33A, these values convert to average summer chlorophyll concentrations ranging from 20 to 22 $mg \cdot m^{-3}$. The Jones and Lee model predicts the

Table 22. Comparison of temperature (°C) profile for Hyrum Reservoir: Observed data (Drury 1975) and temperature model.

Depth (ft)	May Observed	May Model	July Observed	July Model	October Observed	October Model
0	15.2	12.4	22.0	20.7	14.0	14.8
2	15.0	12.4	22.0	20.7	14.0	14.8
4	14.8	11.3	20.0	20.7	14.0	14.8
5	11.8	11.3	20.0	20.7	13.9	14.8
6	11.5	11.2	20.0	20.3	13.8	14.8
7	10.5	11.2	19.0	19.3	13.7	14.8
8	10.0	10.9	19.0	18.3	13.6	14.8
10	9.0	10.3	18.0	15.7	13.5	14.8
12	8.8	10.0	17.0	13.7	13.4	14.8
14	8.8	9.4	17.0	12.0	13.3	14.8
16	8.8	9.1	16.5	10.9	13.2	14.3
18	8.8	8.9	16.2	10.3	13.1	13.2
20	8.8	8.5	16.0	10.3	13.0	12.4

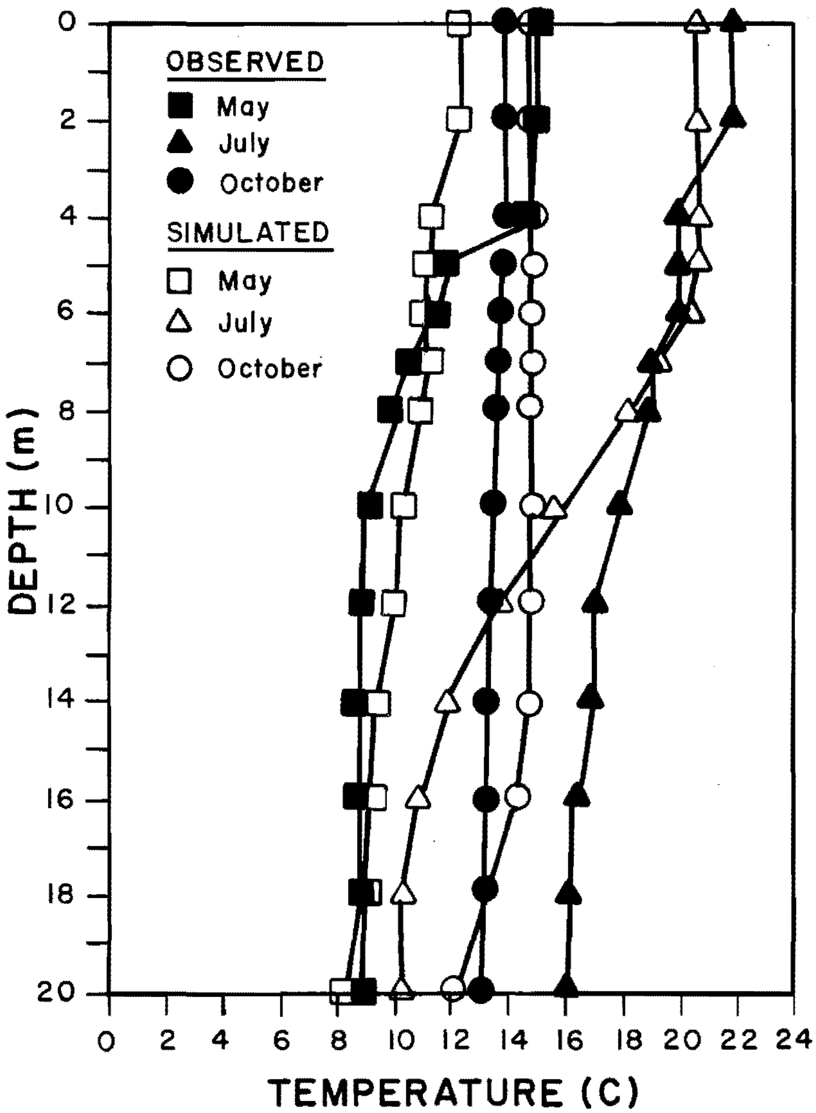


Figure 35. Observed and predicted temperature profiles for Hyrum Reservoir.

Table 23. Empirical trophic state model results for Hyrum Reservoir. Mean summer conditions are predicted.

	Case 1	Case 2
Input Conditions		
Surface Area (x 10^6 ft^2)	20.9	18.6
Volume (x 10^6 ft^3)	812	575
Depth (ft)	38.9	31
Flow (x 10^9 $ft^3 \cdot y^{-1}$)	4.5	4.5
Hydraulic Residence Time (y)	0.18	0.13
Surface Hydraulic Loading ($ft \cdot y^{-1}$)	213	239
Phosphorus Loading (x 10^{-3} $lb.ft^2 \cdot y^{-1}$)	2.0	2.3
Predicted Phosphorus Concentration		
Vollenweider (1975)	133	135
Vollenweider (1976)	107	113
Larson and Mercier (1976)	130	136
Jones and Bachman (1976)	115	119
Kirchner and Dillon (1975)	200	197
Mueller (1982)	102	111
Predicted Trophic Indicator Levels (Jones and Lee 1982)		
Chlorophyll *a* ($mg \cdot m^{-3}$)	22	22
Secchi Depth (m)	1.5	1.5
Hypolimnetic Oxygen Depletion Rate (g $O_2 \cdot m^{-2} \cdot d^{-1}$)	0.7	0.7

Conversion factors

1 m = 3.281 ft
1 m^2 = 10.76 ft^2
1 m^3 = 35.31 ft^3
1 $mg \cdot m^{-2} \cdot y^{-1}$ = 2.05 x 10^{-7} $lb \cdot ft^{-2} \cdot y^{-1}$

Table 24. Logan River above confluence with Little Bear at 376 crossing (station 490504). Average summary by month.

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. °C	NA	3.324	6.05	6.599	10.0	11.06	12.49	18.140	13.145	10.150	6.844	4.366
DO	NA	9.77	11.695	9.699	7.55	11.126	9.149	8.249	8.249	6.999	8.995	9.6
NO_2 & NO_3	0.400	0.460	0.425	0.420	0.225	1.683	0.295	0.640	0.497	0.420	0.33	0.417
NH_3 & NH_4	1.0	0.1	1.0	0.10	0.550	0.4	0.550	0.400	0.1	0.550	0.10	0.100
Total-P	0.4	0.037	0.07	0.40	0.065	0.04	0.06	0.04	0.057	0.045	0.02	0.06
BOD_5	2.0	NA	2.0	NA	1.0	NA	NA	NA	NA	1.0	NA	NA
Flow												
NO_3	NA	0.325	0.550	NA	0.20	0.2	NA	0.85	0.35	0.550	NA	0.5
Ortho-P	NA	0.020	0.020	NA	0.03	0.02	NA	0.02	0.02	0.03	NA	0.02
Flows ($\bar{x}$)												
1976	126	122	130	256	711	600	332	221	187	159	133	114
1977	107	97.9	94.7	128	163	164	109	94.4	82.1	83.6	83.1	81.3
1978	76.4	79.0	128	309	602	885	470	249	194	159	133	112
1979	103	96.3	105	189	579	494	259	179	140	123	111	101
1980	103	103	109	289	709	785	416	243	200	168	138	111
1981	106	103	103	154	338	408	203	138	121	112	98.1	94.7
1982	90.8	104	140	299	946	1013	631	318	244			
$\hat{x}$	102	101	116	232	578	621	346	206	167	134	116	102
$\hat{s}$	15	13	17	74	258	295	176	75	55	33	22	13

Table 25. Little Bear River above confluence with Logan River (station 490500). Average summary by month.

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. °C	3.25	2.625	5.175	6.199	8.948	15.857	17.995	19.568	17.593	13.095	7.996	3.9
DO	11.79	8.995	10.795	9.299	8.620	7.799	8.099	8.474	8.163	5.849	9.563	10.06
NO_2 & NO_3	1.175	1.012	0.9	0.760	0.283	0.563	1.859	1.068	1.173	1.292	1.75	1.099
NH_3 & NH_4	2.100	0.15	0.3	0.10	0.10	0.400	0.367	0.150	0.10	0.425	0.550	0.40
Total-P	0.073	0.082	0.110	0.06	0.115	0.080	0.127	0.314	0.127	0.130	0.240	0.1
BOD_5	2.133	NA	1.999	NA	2.532	NA	2.499	1.299	2.5	1.450	1.799	NA
Flow												
NO_3	0.950	1.05	1.033	NA	0.450	0.8	1.05	1.266	0.890	1.549	1.386	1.149
Ortho-P	NA	0.04	0.04	NA	0.045	0.06	0.07	0.123	0.02	0.03	NA	0.02
Flows ($\bar{x}$)												
1976	27.6	32.8	48.2	133	171	73.5	37.9	30.6	26.6	25.0	23.1	22.2
1977	21.5	21.7	22.3	31.3	53.7	29.5	17.9	16.4	16.4	14.7	15.4	19.5
1978	20.7	30.3	91.5	149	159	113	44.2	30.2	27.4	24.8	25.0	20.5
1979	22.6	24.4	47.8	102	147	61.4	30.2	24.4	21.2	23.4	21.3	20.3
1980	55.9	46.5	40.6	156	196	145	56.4	36.2	31.4	29.0	28.4	29.4
1981	25.6	27.7	37.4	57.4	81.1	41.3	20.2	16.5	16.3	20.6	20.3	26.7
1982	25.5	50.3	90.4	176	223	140	66.5	39.7	39.8			
$\hat{\bar{x}}$	28	33	54	115	147	86	39	28	26	23	22	20
$\hat{s}$	12	11	27	54	60	47	18	9	8	5	4	6

following average summer parameter values: 1) chlorophyll 22 $mg \cdot m^{-3}$, 2) Secchi depth 1.5 meter, and 3) hypolimnetic oxygen depletion rate 0.7 g $O_2 \cdot m^{-2} \cdot day^{-1}$.

Water Quality Simulation Model

Hyrum Reservoir was divided into several spatial elements as shown in Figure 34, ranging from 600 m^2 to 6000 m^2 in cross-sectional area with an average area of 3090 m^2. 1972-1973 flows were input for the simulation.

Two inflow phosphorus concentrations were used, 0.070 and 0.035 $mg \cdot m^{-3}$. The first was estimated by taking the average ortho-P values measured by Drury (1975) in the Little Bear River and assuming that 85 percent of the total would be available to the algae. The second was based on the assumption that only 45 percent of the total influent phosphorus would be available to the algae. Observed nitrogen loadings were: nitrite 0.029 mg $N \cdot m^{-3}$, nitrate 0.981 mg $N \cdot m^{-3}$, and ammonia 0.214 mg $N \cdot m^{-3}$.

Two levels of zooplankton concentrations were used with 0.035 $mg \cdot m^{-3}$ P loading, no zooplankton growth and zooplankton growth. Drury (1975) observed wide variations in zooplankton populations and attributed lower algae cell counts in 1972 to high zooplankton concentrations.

Results from RESEN, the Water Quality Simulation Model, are shown in Table 26. The model calculated average monthly chlorophyll concentrations and the highest values are recorded in Table 26. Total chlorophyll concentrations of 35.5 and 11 $mg \cdot m^{-3}$ were calculated for the 0.070 $mg \cdot m^{-3}$ P (without zooplankton growth) and 0.035 $mg \cdot m^{-3}$ (with zooplankton growth) inflow phosphorus concentrations, respectively. Both of the calculated chlorophyll concentrations fall within the eutrophic classification (Table 19).

Chlorophyll concentrations along the length of Hyrum Reservoir are shown in Figures 36A and B. Figure 36A illustrates algal growth for phosphorus loading of 70 $\mu g \cdot \ell^{-1}$ and no growth of zooplankton. No growth of zooplankton is used to simulate the lower zooplankton concentrations observed by Drury (1975). Figure 36B illustrates algal growth for phosphorus loading of 35 $\mu g \cdot \ell^{-1}$ and includes zooplankton growth. With zooplankton growth included in the model the maximum chlorophyll concentration decreases and the dominant algal species shifts from diatoms to blue-green algae. In both cases chlorophyll concentrations increase rapidly and then decrease.

Water Quality Results

Observed maximum chlorophyll concentrations in Hyrum Reservoir (Drury 1975) ranged from 9 $mg \cdot m^{-3}$ in the summer of 1972 to 102 $mg \cdot m^{-3}$ in the summer of 1973. This large difference in observed values between the two years may be explained by the hydraulic conditions. In 1972 the reservoir was stratified and experienced inflows that were 60 percent above normal. In addition, Drury expressed an opinion that high zooplankton grazing occurred during 1972. In 1973 the reservoir was artificially mixed. In addition to destratifying the reservoir, the temperatures were altered and the mixing may have generated significant phosphorus loading from bottom deposits (Drury 1975).

Observed weighted average chlorophyll concentrations in Hyrum Reservoir (Drury 1975) ranged from 4 $mg \cdot m^{-3}$ in the summer of 1972 to 33.7 $mg \cdot m^{-3}$ in the summer of 1973. The weighted average is calculated by averaging the chlorophyll concentration measured at different depths. RESEN also calculates the weighted average chlorophyll concentration, so comparisons are best done between Drury's weighted average values and RESEN's results. Drury attributed the large difference between 1972 and

Table 26. Results from the RESEN model for average flow into Hyrum Reservoir.

	Temperature °C	Initial P mg/l	Maximum Month Chlorophyll Concentration $mg \cdot m^{-3}$	Phytoplankton Cells/ml
Hyrum				
No zooplankton growth	18	0.07	35.5	344×10^3
Includes zooplankton growth	18	0.035	11	122.3×10^3
No zooplanktion growth	18	0.035	16.1	162×10^3
Honeyville				
No zooplankton growth	18.7	0.054	23	225×10^3
Amalga (Main Body)				
Decreasing extinction coefficient	20	0.034	32	320×10^3
Constant extinction coefficient 4.5	20	0.034	0.8	8×10^3
Amalga (Cub River Branch)				
Blue Green	18	0.38	6.8	84×10^3
Diatom	18	0.38	287.8	$2,780 \times 10^3$
Cutler	18	0.034	<0.8	$>8 \times 10^3$
Oneida	22	0.041	0.9	9×10^3
Mill Creek	17	0.035	12	118×10^3
	17	0.004	2.4	26×10^3
Avon	17	0.049	16.8	165×10^3
	17	0.012	7.1	71.6×10^3

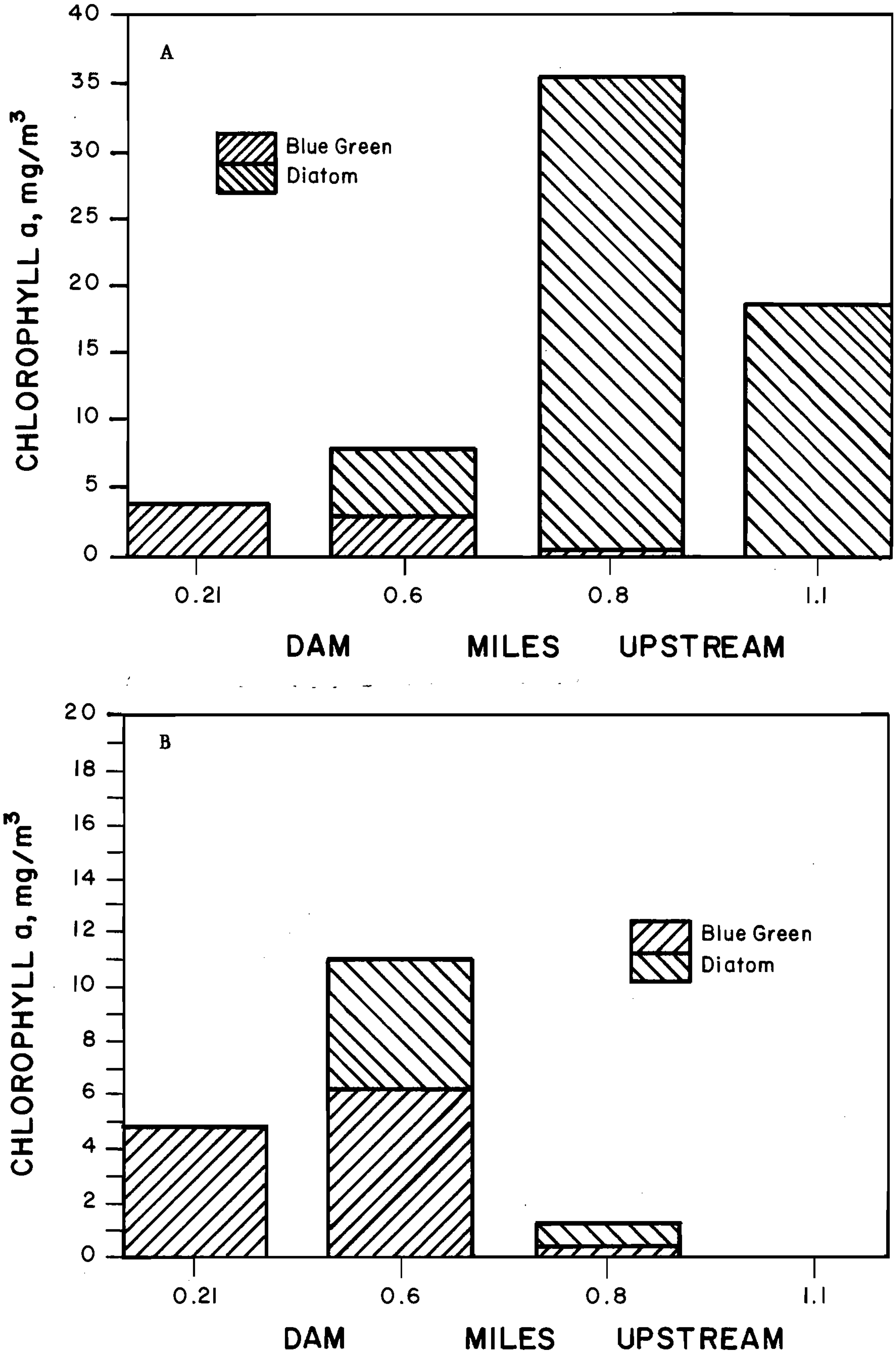


Figure 36. Predicted chlorophyll concentration along the length of Hyrum Reservoir. Part A has no zooplankton growth and 70 $\mu g\ P \cdot \ell^{-1}$. Part B includes zooplankton growth and 35 $\mu g\ P \cdot \ell^{-1}$.

1973 to the hydraulic conditions discussed above and differences in zooplankton concentrations.

The empirical trophic loading models predicted average summer chlorophyll concentrations of 20 to 22 $mg \cdot m^{-3}$. Jones and Lee (1982b) observed that peak summer chlorophyll concentrations may be about 1.7 times the average; this calculation results in an estimated peak concentration between 34 and 38 $mg \cdot m^{-3}$. The simulation model, RESEN, predicted high average monthly chlorophyll concentrations of between 11 and 35.5 $mg \cdot m^{-3}$.

In summary, the models agree among themselves and the predicted results fall within the range of observed values, which probably represent one unusually low event and one unusually high event. Both the predicted and the observed values represent eutrophic conditions. This result demonstrates an important limitation of screening level models: they may be able to predict general conditions (i.e., oligotrophic, mesotrophic, eutrophic) based on average parameter values, but the short term parameter values will vary significantly from year to year in the prototype. The loading rate of bioavailable phosphorus was found to be the most sensitive parameter for empirical trophic state models and the simulation model. Results from the simulation model, RESEN, could probably be improved by: 1) better representation of actual hydraulic conditions, 2) improved algorithms for zooplankton grazing, and 3) introduction of benthic phosphorus loading.

Cutler Reservoir Application

Cutler Reservoir, Figure 37, is a narrow shallow river run reservoir (depth 1 - 3 feet over much of the reservoir) about 5 miles long. Average annual flow is 22 x 10^9 ft^3 (524697 acre-feet$\cdot y^{-1}$). Limited limnological data are available for Cutler Reservoir. Observations during the summer of 1984 and spring of 1985 indicated Cutler Reservoir does not stratify and remains turbid throughout its length. From observations made during 1984 the writers concluded high turbidity limited algal growth.

Extinction Coefficient

Measured extinction coefficient values are given in Table 20. From these values it can be seen that turbidity is high averaging 4.9 m^{-1}, and does not decrease significantly with distance over the length of the reservoir.

Water Quality Simulation Model

RESEN was applied to Amalga Reservoir (flow and geometry) using an extinction coefficient of 4.9 m^{-1} found in Cutler. The geometry of the proposed Amalga Reservoir is similar to Cutler, both are shallow river run reservoirs.

Water Quality Results

RESEN predicts chlorophyll concentrations of less than 0.8 $mg \cdot m^{-3}$ as shown in Table 26. No chlorophyll measurements were made during 1984 so exact comparison to chlorophyll concentrations in Cutler Reservoir is not possible; however, observations made during 1984 did not identify any algal blooms. It is assumed that algal concentrations during the summer of 1984 were less than 5 $mg \cdot m^{-3}$. In this case, RESEN adequately simulates algal growth inhibition due to low light penetration.

Amalga Reservoir Application

The proposed Amalga Reservoir, Figure 38, will be a river-run reservoir approximately 13 to 18 miles long, narrow, and relatively shallow with an average depth of only about 10.5 feet (3.2 m). Average annual flow will be about 46 x 10^9 $ft^3 \cdot y^{-1}$ (1.0 x 10^6 $AF \cdot y^{-1}$). The Cub River is a tributary to the Bear River approximately 4 miles upstream from the proposed dam site, and

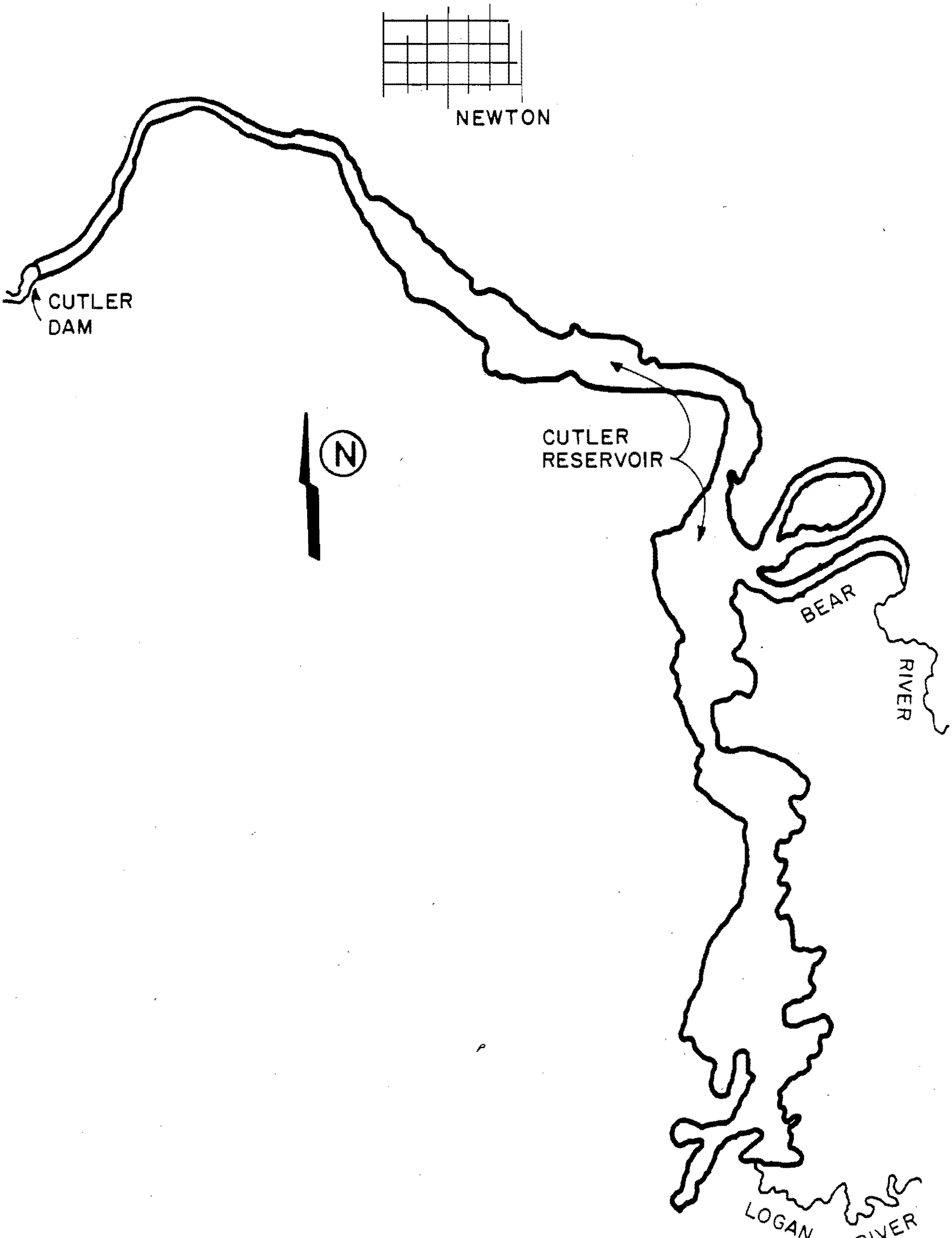


Figure 37. Cutler Reservoir.

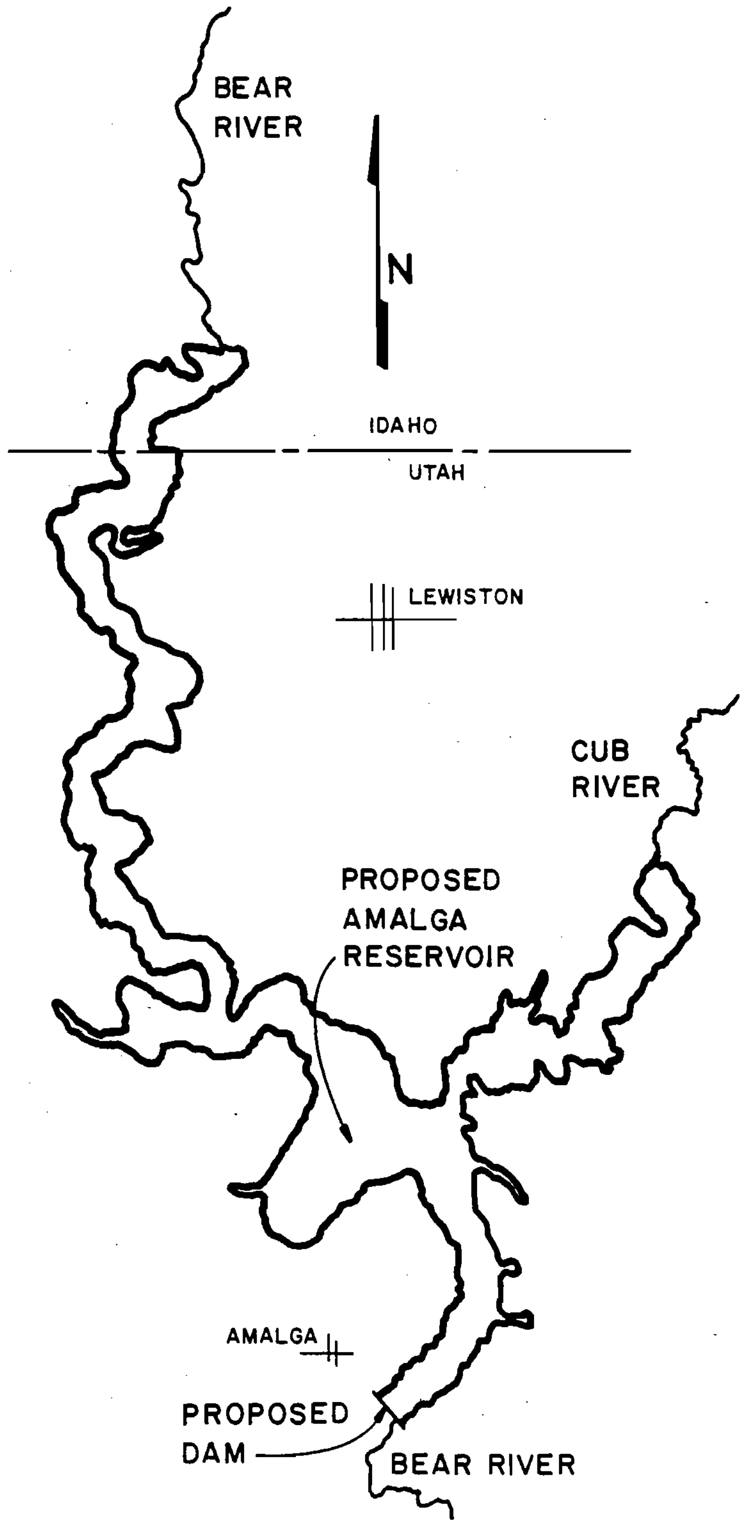


Figure 38. Amalga Reservoir.

will form a significant arm to the reservoir east of the main waterbody. Tables 27 and 28 summarize flow and water quality data for the Bear and Cub Rivers, respectively.

Water Temperature Model

The temperature model was applied for the months April through October using inflows recorded for the Bear River at the Utah-Idaho state line. The meteorological data used for the simulation are shown in Appendix D.

The maximum temperature gradient tends to occur in July, but no significant stratification develops. The model was run for both low flow and high flow conditions with no significant difference between the profiles except for slightly warmer surface temperatures during low flow conditions. The model indicates very weak temperature profiles for most of the length of the reservoir.

A deeper pool will be created between the confluence of the Cub and the dam site, reaching a depth of about 35 feet, which may be susceptible to stratification. The model was applied to this pool area and the profiles predicted for July and August are shown in Figure 39. Figure 40 shows the predicted temperatures for the surface and bottom of the pool as a function of time. The Bear River inflow temperatures are also shown and appear to be near equilibrium. It can be seen from the figures that the maximum gradient tends to occur in July, but that no significant stratification develops. However, it is possible that occasionally a strong thermocline may occur for a sufficient period of time to cause water quality problems.

Suspended Sediment

Some rough estimates were made of the sediment trapping efficiency for the proposed Amalga Reservoir. Preliminary results follow (ASCE 1977):

	Fine Silt	Fine Sediment	Median Curve	Coarse Sediment
Brune method		75%	85%	92%
Churchill method	30%			

In a sample of the Bear River taken in December 1984, all of the suspended sediment passed a #400 sieve (less than 35 microns). It is estimated that most of the sediment of this size would pass through the reservoir.

Empirical Trophic State Models

The empirical trophic state models were applied to the proposed Amalga Reservoir for three flow conditions; low, average, and high. Flow and phosphorus loading data are shown in Tables 29 and 30. Results of the analysis are shown in Table 30.

Predicted average waterbody phosphorus concentrations range from 79 to 141 mg $P \cdot m^{-3}$. Using Figure 33A, these values convert to average summer chlorophyll concentrations ranging from 18 to 22 $mg \cdot m^{-3}$. The Jones and Lee model predicts the following average summer parameter values: 1) chlorophyll 10 to 15 $mg \cdot m^{-3}$, 2) Secchi depth 2 to 1.6 meters, and 3) hypolimnetic oxygen depletion rate of 0.5 to 0.6 g $O_2 \cdot m^{-2} \cdot d^{-1}$.

Water Simulation Model

The water quality simulation model, RESEN, was applied to the proposed Amalga Reservoir using low flow conditions, an average influent phosphorus concentration, and both constant and decreasing extinction coefficients. The highest average monthly chlorophyll concentration was 32 $mg \cdot m^{-3}$ (for decreasing extinction coefficient) as shown in Table 26. Figures 41A and B show the simulated chlorophyll concentration along the length of Amalga

Table 27. Bear River, Utah-Idaho state line (station 490610). Average summary by month.

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. °C	1.75	0.725	4.575	8.25	13.5	13.523	20.645	20.895	21.327	10.745	4.496	1.5
DO	12.99	9.399	11.195	9.445	7.929	9.129	8.366	7.5	8.763	7.4	10.326	9.75
NO_2 & NO_3	0.925	0.885	0.966	0.585	0.450	0.243	0.37	0.256	0.320	0.386	0.4	1.05
NH_3 & NH_4	0.167	0.125	0.340	0.10	0.10	0.4	0.367	0.1	0.075	0.26	0.225	0.25
Total-P	0.073	0.097	0.143	0.10	0.07	0.06	0.063	0.076	0.07	0.078	0.108	0.75
BOD_5	1.866	NA	1.999	1.299	2.5	NA	2.65	1.799	3.0	1.999	4.7	NA
Flow (csf)												
NO_3	0.6	0.475	1.012	0.65	0.333	0.3	0.2	0.383	0.120	0.575	0.775	NA
Ortho-P	0.01	0.04	0.05	0.025	0.03	0.02	0.055	0.04	0.03	0.025	0.02	NA
Flows ($\bar{x}$)												
1976	1655	1959	1527	2026	1736	667	754	562	823	961	1124	1126
1977	1197	650	552	480	695	746	824	567	411	258	355	519
1978	571	650	1077	1746	1715	819	696	701	446	566	549	589
1979	606	588	883	1234	942	395	820	619	443	533	453	330
1980	825	787	708	1395	2660	2606	1028	1223	1550	1553	1321	1238
1981	1041	721	563	564	724	706	761	821	450	487	328	310
1982	488	725	911	1430	1960	1206	473	1117	1588			
$\hat{\bar{x}}$	826	869	789	1268	1405	1021	765	801	816	726	688	685
$\hat{s}$	535	485	476	572	595	739	166	269	534	464	426	401

Table 28. Cub River above confluence with Bear River (station 490370). Average summary by month.

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. °C	3.0	0.5	4.266	8.75	13.2	10.73	12.79	18.790	18.3	9.699	7.9	2.15
DO	12.19	9.899	11.04	8.45	11.79	10.763	7.399	3.299	9.645	8.0	9.15	9.845
NO_2 & NO_3	NA	1.799	2.199	1.345	NA	0.260	0.7	1.699	1.0	1.074	0.555	1.524
NH_3 & NH_4	0.3	0.3	0.8	0.2	0.1	0.4	1.0	0.100	0.10	0.550	0.1	0.6
Total-P	0.240	0.2	0.293	0.110	NA	0.113	0.25	0.750	0.150	0.125	0.065	0.195
BOD_5	2.099	NA	3.2	2.0	7.5	NA	NA	NA	5.0	NA	NA	NA
Flow												
NO_3	1.549	NA	1.624	0.85	0.450	0.250	NA	NA	0.650	NA	NA	NA
Ortho-P	0.11	NA	0.34	0.04	0.270	0.050	NA	NA	0.140	NA	NA	NA
Flows ($\bar{x}$)												
1976	21.6	22.9	24.8	70.0	363	285	89.3	44.2	32.3	27.1	22.2	18.6
1977	18.1	14.5	15.0	43.5	77.5	73.5	28.5	21.9	18.0	16.4	14.1	15.1
1978	16.0	17.0	41.8	101	243	463	166	56.4	35.8	28.6	26.2	23.4
1979	18.1	16.0	22.5	50.3	298	214	69.5	37.2	27.3	24.5	20.4	16.8
1980	17.5	18.4	21.8	108	328	411	113	49.6	34.5	27.6	23.4	20.3
1981	18.1	15.8	20.4	55.6	238	209	58	38.4	30.1	23.4	20.3	20.5
1982	19.6	22.5	32.3	69.7	373	537	195	71.8	50.7			
$\hat{\bar{x}}$	18.4	18.2	25.5	71.2	274	313	103	46	33	25	21	19
$\hat{s}$	1.7	3.3	8.7	24.8	101.7	164	50	16	10	5	4	3

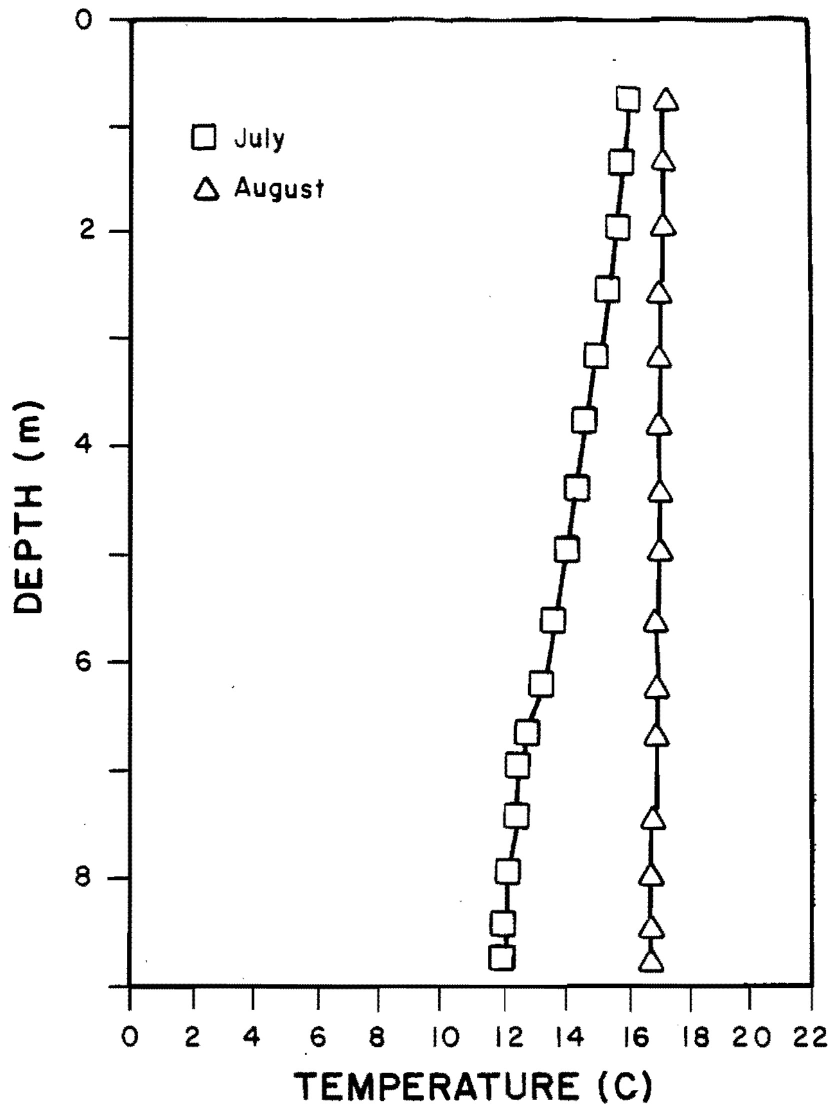


Figure 39. Predicted temperature profiles for the Amalga pool during July and August.

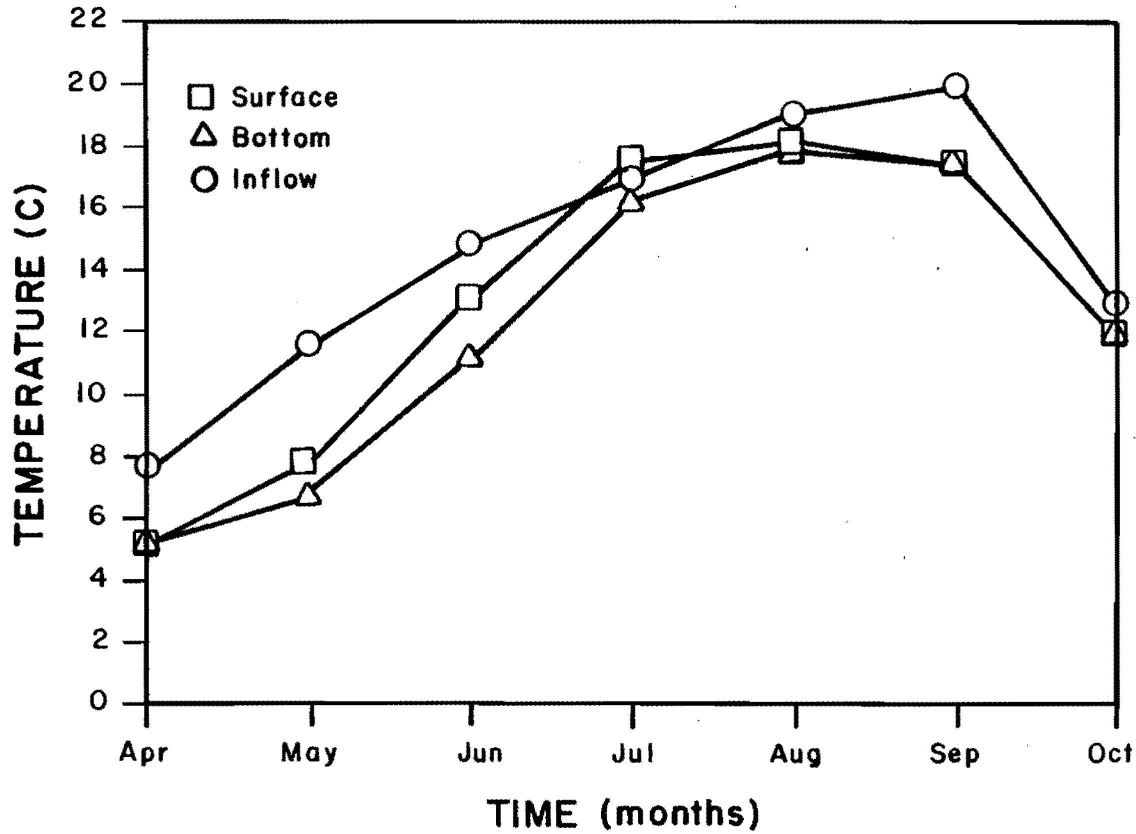


Figure 40. Predicted temperature variations for the Amalga pool during April through October.

Table 29. Flow and phosphorus concentration data for Amalga Reservoir (STORET 490368)

Month	Flow (cfs) High ('80)	Low ('79)	Ave. (77-83)	Temperature (1980)	(1979)	Ave. (77-83)	P-O (77-83)	P-Total (77-83)
J	843	624	844			0.500		0.080
F	887	604	887	2.7		3.850	0.05	0.170
M	730	906	814			6.599		0.200
A	1503	1284	1339	6.4		9.450	0.08	0.050
M	2388	1240	1679			15.245	0.045	0.130
J	3017	609	1334	18.8		16.090		0.100
J	1141	889	868	21.6		20.470	0.03	0.367
A	1273	656	847	24.1		21.295	0.170	0.125
S	1585	470	849	20.6		21.627	0.07	0.190
O	1581	558	751	14.4		11.995		0.145
N	1344	473	709	11.3		6.563	0.08	0.067
D	1258	327	704	0.9		1.599		0.110

Table 30. Empirical trophic state model results for Amalga Reservoir.

	Low Flow	Average Flow	High Flow
Approximate Surface Area (ft^2)	250×10^6	250×10^6	250×10^6
Approximate Volume (ft^3)	2.65×10^9	2.65×10^9	2.65×10^9
Average Depth (ft)	10.6	10.6	10.6
Flow ($ft^3 \cdot y^{-1}$)	2.3×10^{10}	3.1×10^{10}	4.6×10^{10}
Hydraulic Residence Time (years)	0.116	0.087	0.58
Surface Hydraulic Loading (qs $ft \cdot y^{-1}$)	91	122	184
Phosphorus Loading (mg $P \cdot m^{-2} \cdot y^{-1}$)	4075	5208	7662
Average P ($mg \cdot m^{-3}$) (Vollenweider 1975)	108	110	116
Average P ($mg \cdot m^{-3}$) (Vollenweider 1976)	110	108	110
Average P ($mg \cdot m^{-3}$) (Larson and Mercier 1976)	132	129	129
Average P ($mg \cdot m^{-3}$) (Jones and Bachman 1976)	115	111	110
Average P ($mg \cdot m^{-3}$) (Kirchner and Dillon 1975)	212	197	182
Average P ($mg \cdot m^{-3}$) (Mueller 1982)	109	110	114
Jones and Lee (1982b)			
Mean Summer Chlorophyll a ($mg \cdot m^{-3}$)	19	19	19
Mean Summer Secchi Depth (m)	1.6	1.6	1.6
Hypolimnetic Oxygen Depletion Rate (g $O^2.m^{-2} \cdot d^{-1}$)	0.7	0.7	0.7
λ	110	108	110

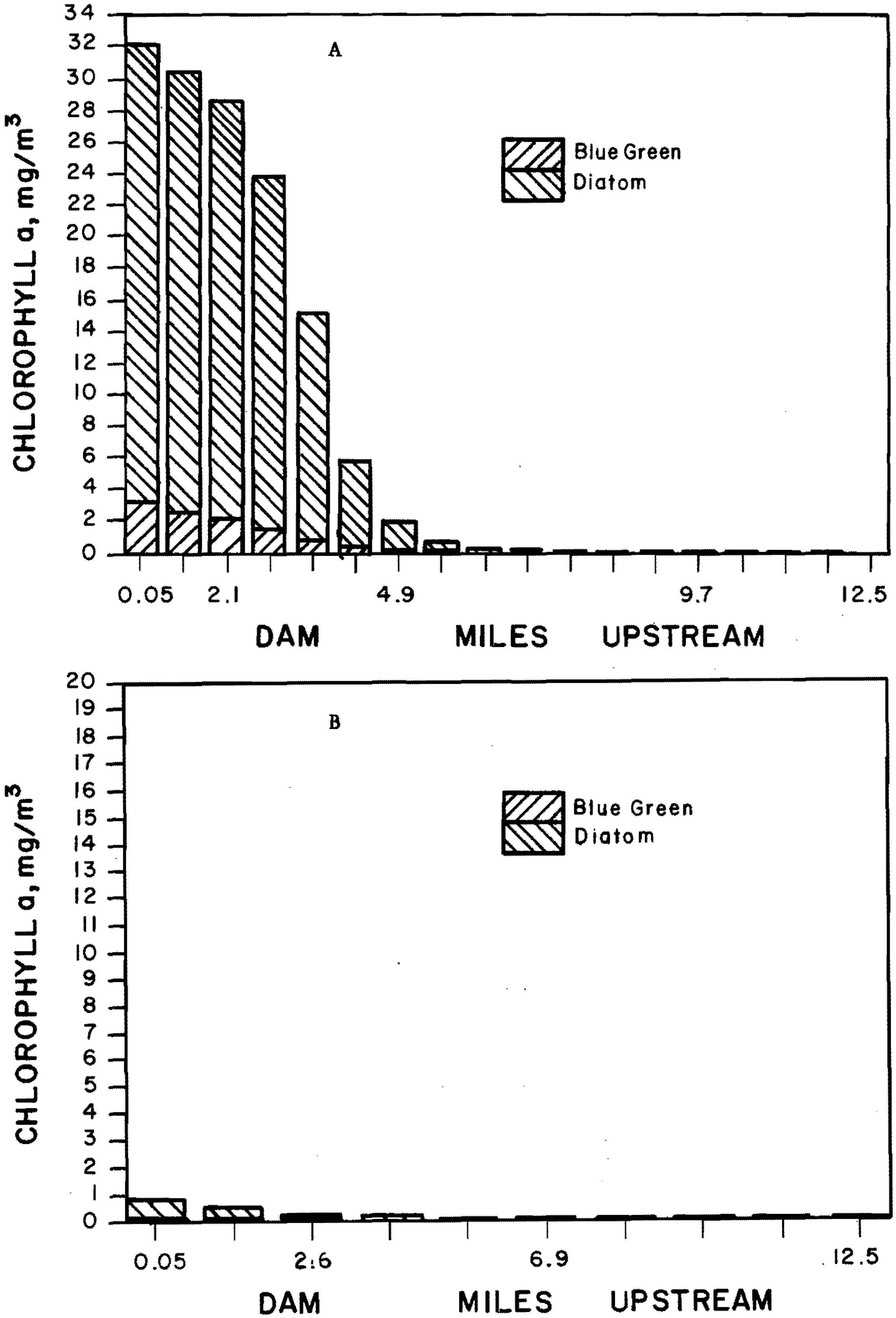


Figure 41. Predicted chlorophyll concentrations along the length of Amalga Reservoir. Part A simulates decreasing turbidity, while part B nondecreasing high turbidity.

Reservoir for decreasing and constant turbidity. As shown in Figure 41A, the algal population grows slowly until the vicinity of the dam and then grows rapidly. Light penetration inhibits algal growth over much of the reservoir. With the extinction coefficient held constant at 4.9 m^{-1} the maximum chlorophyll is 0.8 $mg \cdot m^{-3}$ as shown in Table 26 and Figure 41B.

A possible important limitation of the application of the model deals with the resuspension of phosphorus from the bottom sediments. Resuspension was not included in this preliminary application. It is an event that occurs in many shallow eutrophic reservoirs and can contribute significantly to algal blooms.

Because of the high phosphorus loading from the Cub River, the eastern branch of the reservoir was modeled separately. Low flows and average influent phosphorus concentrations were also used in this simulation. The highest average monthly chlorophyll concentration was 294 $mg \cdot m^{-3}$. This parameter is extremely high and would probably not be reached in the prototype because some other nutrient (i.e., silica) would become limiting. In addition, the community composition would probably shift from diatom to blue-green algae causing very undesirable conditions.

Water Quality Results

The empirical trophic loading models predict average summer chlorophyll concentrations of 18 to 22 $mg \cdot m^{-3}$ for the main body of the reservoir. Based on these values, peak concentrations would be expected to be in the range of 31 to 38 $mg \cdot m^{-3}$. The simulation model, RESEN, predicted high average monthly chlorophyll concentrations of 32 $mg \cdot m^{-3}$ in the main body of the reservoir near the dam. These values indicate eutrophic conditions. Although oxygen depletion rates are high, the main body of the reservoir does not stratify and, as a general rule, anoxic conditions will not develop.

For the Cub River branch of the Amalga Reservoir, the simulation model predicts severe eutrophic conditions. Extremely poor water quality can be expected in this area. The relatively deep pool near the dam will also be subject to high levels of eutrophication and if the pool becomes thermally stratified from time to time, as it likely will, the high oxygen depletion rates may cause anaerobic conditions in the hypolimnion.

When turbid conditions are assumed to exist throughout the reservoir algal growth is inhibited. Chlorophyll concentrations are predicted to be 0.8 $mg \cdot m^{-3}$ for both the main part of Amalga Reservoir and for the Cub River branch of the Amalga Reservoir. Conditions at Amalga Reservoir could change with time, starting with algal blooms near the dam for the first few years and then algal blooms decreasing as the reservoir fills with sediment and remains turbid throughout its length.

Amalga Reservoir will not remove much of the orthophosphorus in either case. If algal growth is limited by turbidity the phosphorus will pass out of the reservoir in the water. If algal growth does occur it will be close to the dam and the algae will be carried out of the reservoir carrying the phosphorus downstream to be released when the algae decay.

The extinction coefficient was determined to be the most important single parameter effecting algal growth in the simulation model.

Honeyville Reservoir Application

The proposed Honeyville Reservoir, Figure 42, will be a river-run reservoir about 18 miles long with an average depth of about 32 feet (9.8 m). Average annual inflow will be about 46 $x10^9$

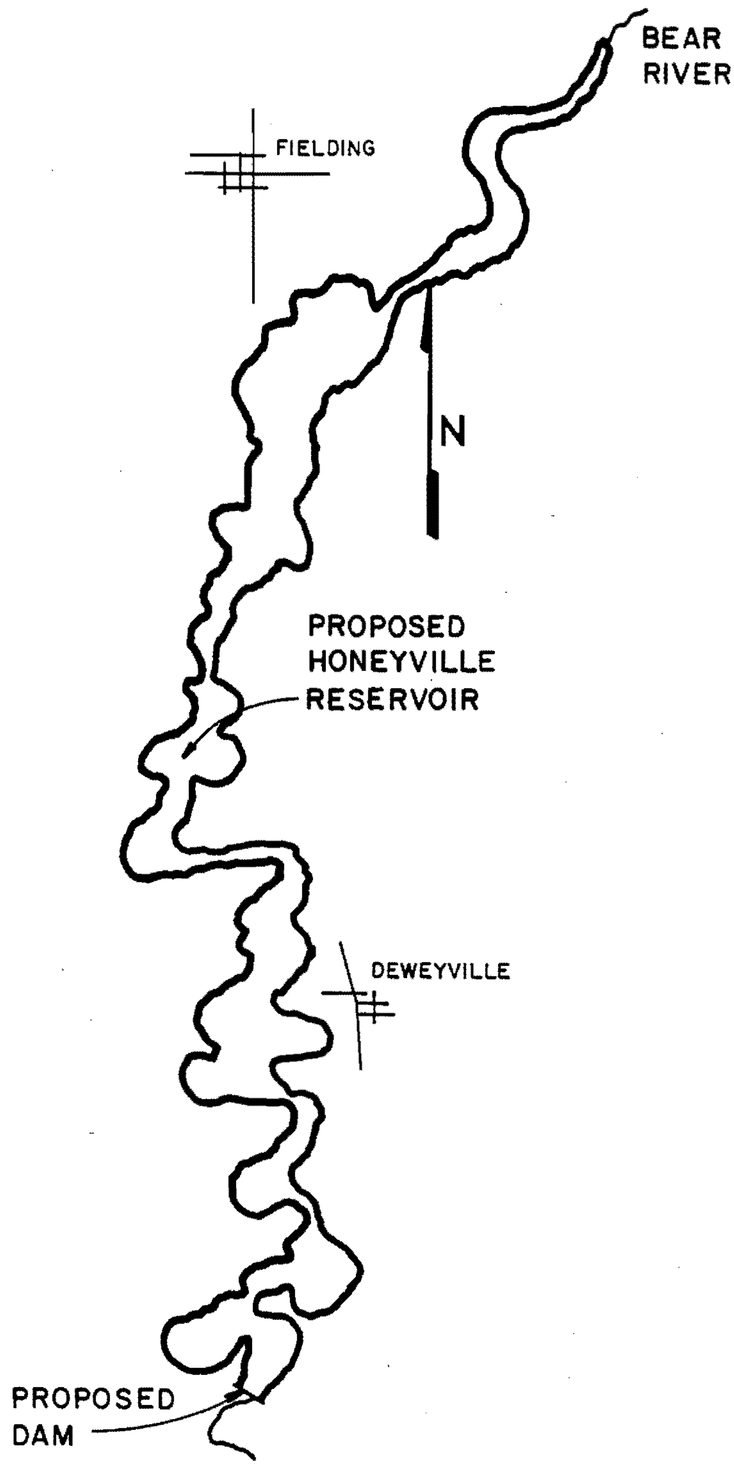


Figure 42. Honeyville Reservoir.

$ft^3 \cdot y^{-1}$ (1.0×10^6 $AF \cdot y^{-1}$). The reservoir will have an irregular shape made up of a series of pools which may cause localized pockets of undesirable conditions. Table 31 summarizes flow and water quality data for the inflow.

Turbidity conditions at Honeyville Reservoir are expected to be between those of Cutler and Oneida Reservoirs. Honeyville Reservoir is deeper than Cutler Reservoir but not as deep as Oneida Reservoir. Turbidity is expected to decrease at a rate similar to Oneida.

Water Temperature Model

The temperature model was applied for the months April through October using inflows and temperatures for the Bear River below Cutler Reservoir. The meteorological data used for the simulation are shown in Appendix E.

Figure 43 shows the predicted temperature profiles for the Honeyville Reservoir during April through October. Figure 44 shows the predicted temperatures for the surface and the bottom as a function of time over the simulation period. The Bear River inflow temperatures are also shown, and these temperatures appear to be near equilibrium. It can be seen from the figures that the maximum gradient occurs in August at depths of 9 to 11 meters. The thermocline will tend to form quite deeply in the reservoir. Figure 45 shows the reservoir volumes above and below the estimated thermocline (at about 11 m) along the reservoir. Only about 18 percent of the reservoir volume is in the hypolimnion and most of that is near the dam. Most of the reservoir volume will be well mixed; however, some hypolimnetic waters can be expected.

Empirical Trophic State Models

The empirical trophic state models were applied to the proposed Honeyville Reservoir for three flow conditions; low, average, and high. Flow and phosphorus concentration data are shown in Tables 32 and 33. Results of the analysis are shown in Table 33.

Predicted average waterbody phosphorus concentrations range from 83 to 159 mg $P \cdot m^{-3}$. Using Figure 33A, these values convert to average summer chlorophyll concentrations ranging from 18 to 22 $mg \cdot m^{-3}$. The Jones and Lee model predicts the following average summer parameter values: 1) chlorophyll 18 to 19 $mg \cdot m^{-3}$, 2) Secchi depth depth 1.5 to 1.6 meters, and 3) hypolimnetic oxygen depletion rate 0.6 g $O_2 \cdot m^{-2} \cdot d^{-1}$.

Water Quality Simulation Model

The water quality simulation model, RESEN, was applied to the proposed Honeyville Reservoir using average flow conditions, an average influent phosphorus concentration and a decreasing extinction coefficient. The highest average monthly chlorophyll concentration would be 23 $mg \cdot m^{-3}$ as shown in Table 26. Figure 46A shows the highest predicted chlorophyll concentration along the length of Honeyville Reservoir would occur for the case of decreasing turbidity with no zooplankton growth. Chlorophyll concentration starts to increase at mile 5.6 and would reach a maximum of 23 $mg \cdot m^{-3}$ at mile 1 and then decrease to 16 $mg \cdot m^{-3}$ at the dam. Growth would be limited to the lower 5.6 miles of Honeyville Reservoir by the high turbidity found in the upper reaches.

As shown in Figure 46B, larger zooplankton concentrations slow the rapid growth of the algae through grazing and lowers the maximum chlorophyll concentration to 9.5 $mg \cdot m^{-3}$ near the dam. The zooplankton could possibly be controlled by zooplanktivorous fish and thereby reduce the suspended solids load to the water treatment plant. Figure 46C shows if turbidity remains high algal growth is inhibited and chlorophyll concentration is kept below 0.5 $mg \cdot m^{-3}$.

Table 31. Bear River below Culter (station 490198, 1/77 - 12/83). Average summary by month.

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. °C	0.750	2.3	2.85	NA	13.245	16.0	21.56	21.745	21.0	11.345	5.833	0.65
DO	13.795	10.592	12.557	NA	9.522	7.733	9.029	8.224	8.663	6.949	10.36	12.45
NO_2 & NO_3	0.825	0.897	0.999	0.640	0.317	0.470	0.255	0.288	0.410	0.332	0.585	0.6
NH_3 & NH_4	0.133	0.180	0.400	0.100	0.100	0.400	0.3	0.1	0.1	0.325	0.1	0.55
Total-P	0.1	0.127	0.142	0.120	0.130	0.130	0.12	0.102	0.130	0.110	0.103	0.075
BOD_5	1.766	9.5	2.699	NA	2.866	NA	3.0	4.199	4.0	2.3	5.0	9.0
Flow												
NO_3	0.6	0.917	0.999	NA	0.225	0.550	0.125	0.483	0.205	0.65	0.275	NA
Ortho-P	0.02	0.073	0.077	NA	0.045	0.10	0.04	0.063	0.035	0.03	0.02	NA
Flows ($\bar{x}$)												
1976	2048	2188	3171	4470	3904	1646	276	496	1050	1554	1639	1673
1977	1652	1198	1306	766	521	146	105	297	573	354	830	934
1978	1110	1313	2109	3558	3155	1538	141	161	470	773	1109	1181
1979	1122	1285	2520	2478	1822	420	147	149	166	707	988	872
1980	2448	2230	1810	2433	4698	4821	970	831	1671	1872	2098	1989
1981	1787	1217	1117	1171	1171	1232	130	102	180	874	894	1100
1982	1010	1073	2815	3434	5216	2957	692	1022	2015			
$\hat{\bar{x}}$	1452	1500	2121	2615	2927	1823	352	437	875	1022	1260	1292
$\hat{s}$	775	490	765	1326	1802	1608	342	363	730	572	502	444

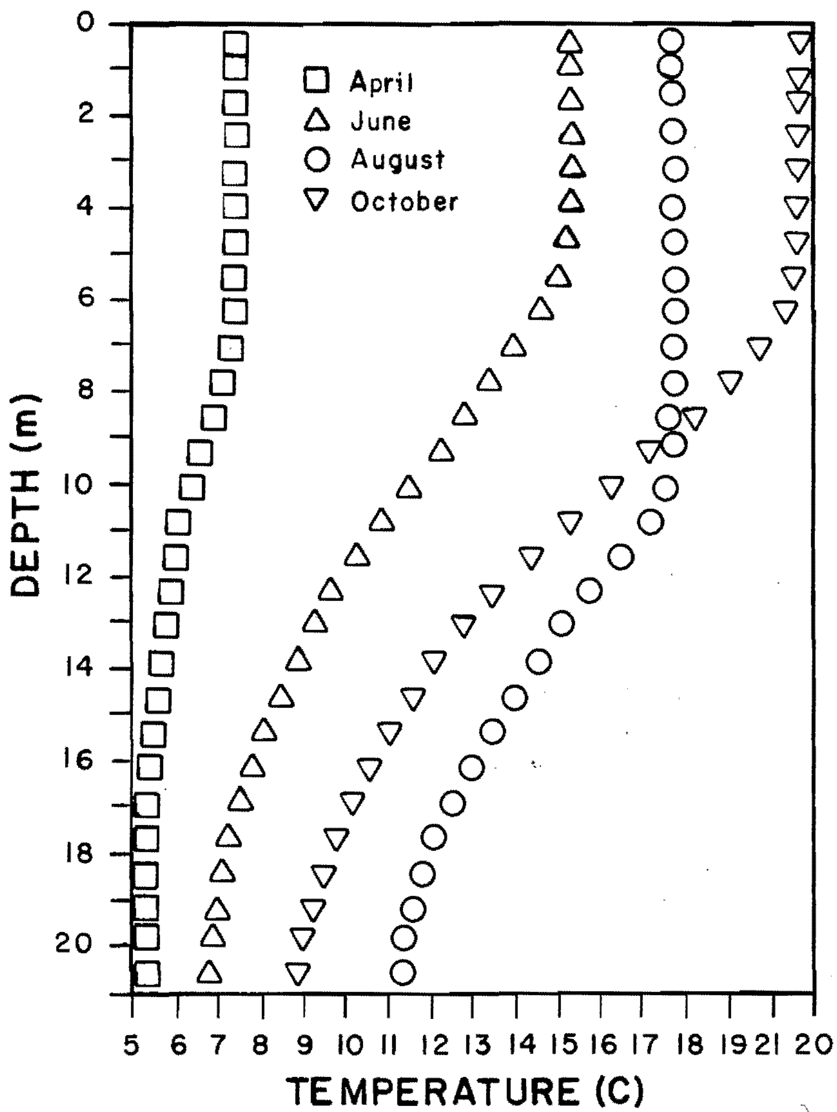


Figure 43. Predicted temperature profiles for the Honeyville Reservoir during April through October.

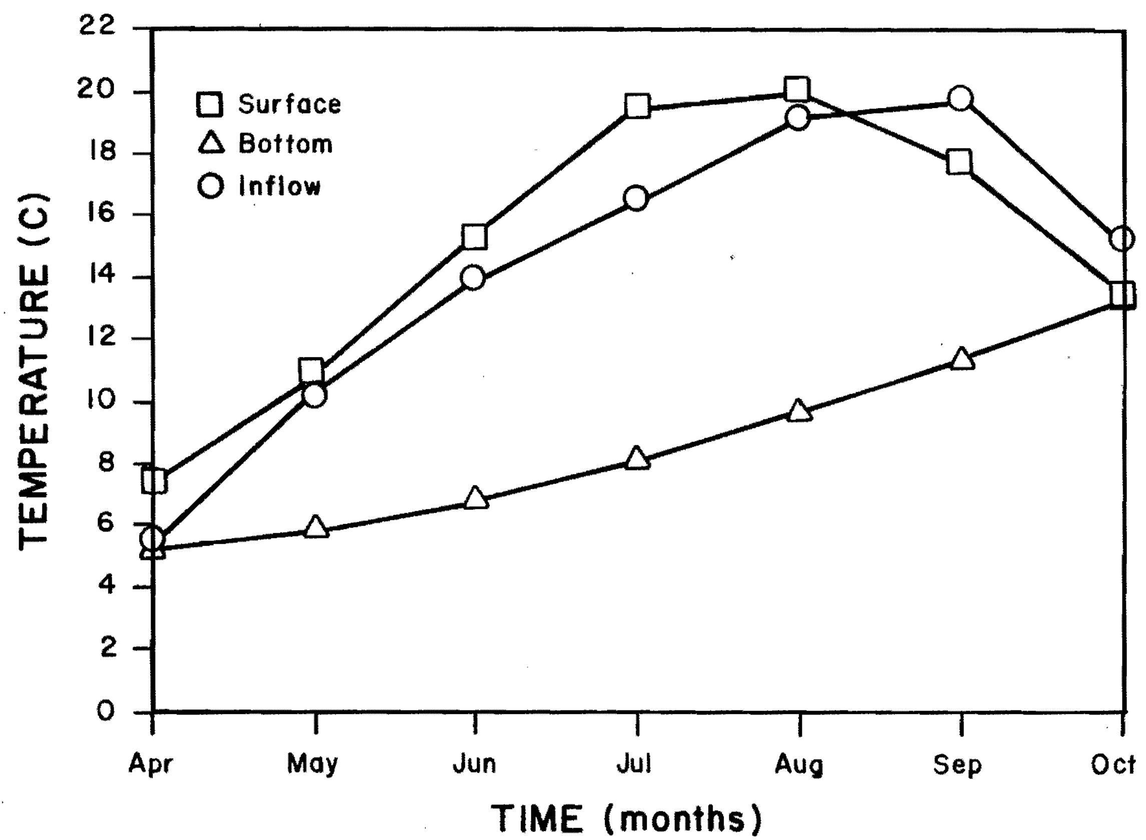


Figure 44. Predicted temperature variations for the Honeyville Reservoir during April through October.

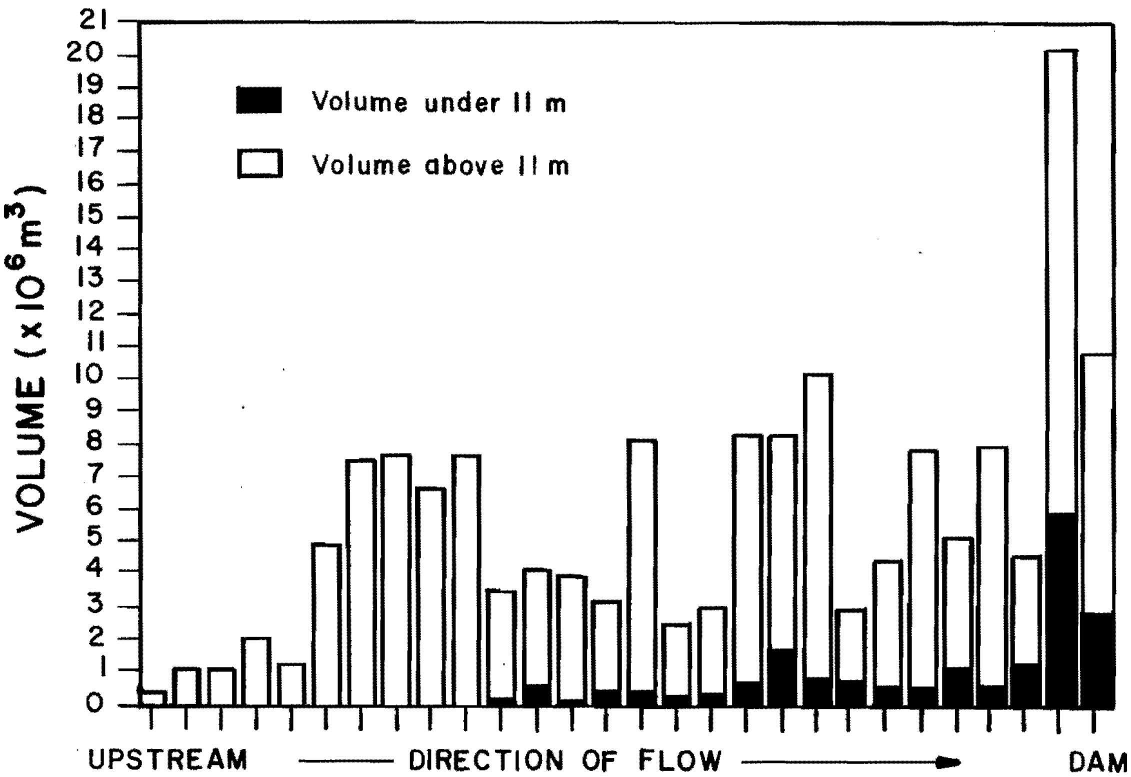


Figure 45. Reservoir volumes above and below the estimated thermocline along Honeyville Reservoir.

Table 32. Flow and phosphorus concentration data for Honeyville Reservoir.

	Flow (cfs)			Temperature				
Month	High ('80)	Low ('79)	Ave. (77-83)	(1980)	(1979)	Ave. (77-83)	P-Orth. (77-83)	P-Total (77-83)
J	2448	1122	1452	0.75	0.75	0.750	0.02	0.100
F	2230	1288	1500	3.1	0.5	2.300	0.073	0.127
M	1810	2529	2121	3.0	3.0	2.850	0.077	0.142
A	2433	2478	2616	9.0	9.0	9.00	0.058	0.120
M	4698	1822	2927	13.3	13.3	13.245	0.045	0.130
J	4821	420	1823	16.5	16.0	16.000	0.10	0.130
J	970	147	352	18.8	22.0	21.560	0.04	0.120
A	831	149	437	22.5	26.0	21.745	0.063	0.102
S	1671	166	875	18.0	21.0	21.000	0.035	0.130
O	1872	707	1022	12.7	11.3	11.345	0.030	0.110
N	2098	988	1260	9.2	5.8	5.833	0.020	0.103
D	1989	872	1292	0.3	0.65	0.650	0.015	0.075

Table 33. Empirical trophic state model results for Honeyville Reservoir.

	Low Flow	Average Flow	High Flow
Approximate Surface Area (ft^2)	160×10^6	160×10^6	160×10^6
Approximate Volume (ft^3)	5.2×10^9	5.2×10^9	5.2×10^9
Average Depth (ft)	32.5	32.5	32.5
Flow ($ft^3 \cdot y^{-1}$)	33×10^9	46×10^9	73×10^9
Hydraulic Residence Time (years)	0.158	0.112	0.071
Surface Hydraulic Loading (q_s $ft \cdot y^{-1}$)	206	290	456
Phosphorus Loading (mg $P.m^{-2} \cdot y^{-1}$)	7,600	10,490	16,480
Average P ($mg \cdot m^{-3}$) (Vollenweider 1975)	104	107	110
Average P ($mg \cdot m^{-3}$) (Vollenweider 1976)	86	89	94
Average P ($mg \cdot m^{-3}$) (Larson and Mercier 1976)	104	106	110
Average P ($mg \cdot m^{-3}$) (Jones and Bachman 1976)	92	92	95
Average P ($mg \cdot m^{-3}$) (Kirchner and Dillon 1975)	159	148	136
Average P ($mg \cdot m^{-3}$) (Mueller 1982)	83	89	96
Jones and Lee (1982)			
Mean Summer Chlorophyll _a_ ($mg \cdot m^{-3}$)	18	18	19
Mean Summer Secchi Depth (m)	1.6	1.6	1.5
Hypolimnetic Oxygen Depletion Rate (g $O_2.m^{-2} \cdot d^{-1}$)	0.6	0.6	0.6
λ	87	89	94

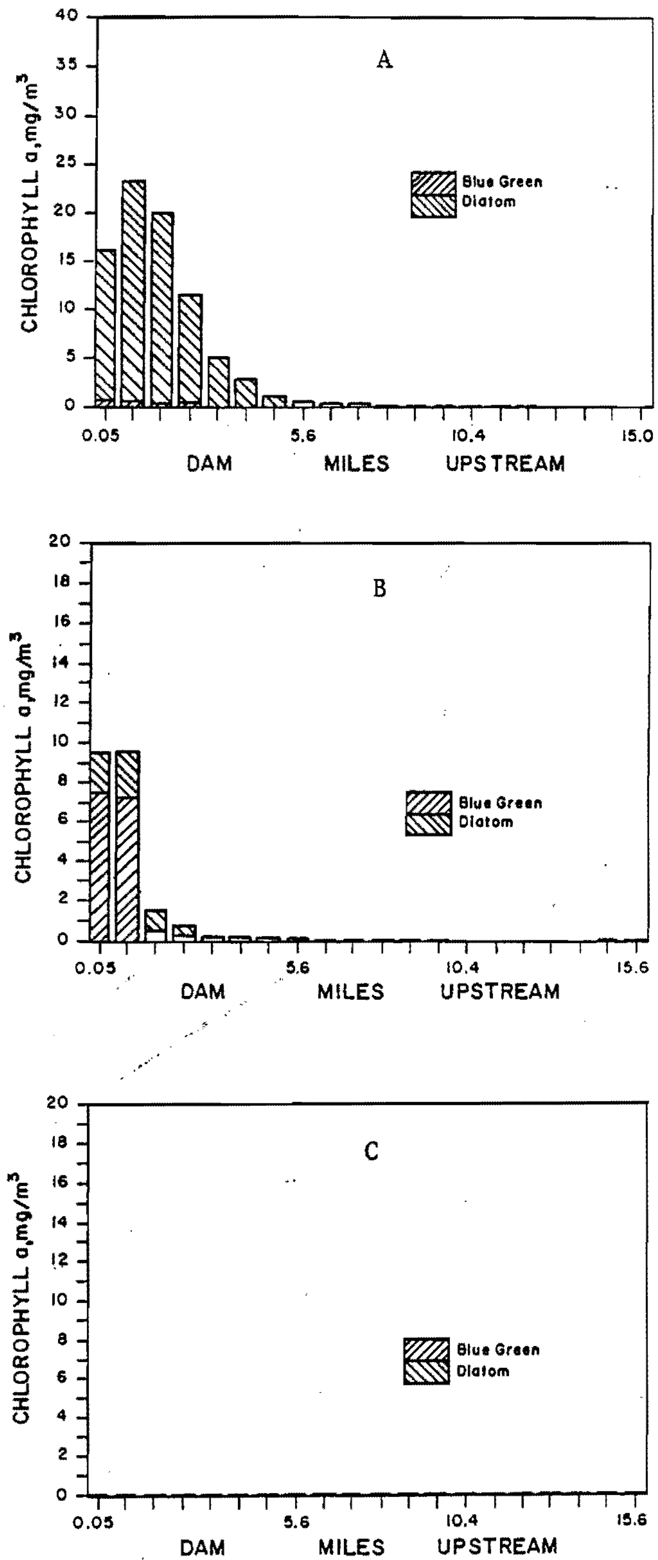


Figure 46. Predicted chlorophyll concentrations along the length of Honeyville Reservoir. Part A illustrates the effect of decreasing turbidity and no zooplankton growth, Part B has decreasing turbidity and zooplankton growth, and Part C has high turbidity and no zooplankton growth.

Water Quality Results

The empirical trophic loading models predict average summer chlorophyll concentrations of 18 to 22 $mg \cdot m^{-3}$. Based on these average values, peak concentrations would be expected to be in the range of 31 to 38 $mg \cdot m^{-3}$. The simulation model, RESEN, predicted high average monthly chlorophyll concentrations of 23 $mg \cdot m^{-3}$. These values indicate eutrophic conditions. The reservoir does tend to stratify, and due to the high oxygen depletion rates, pockets of anoxic hypolimnetic waters may develop.

Turbidity in Oneida Reservoir is expected to decrease to levels permitting eutrophic conditions. Since algal growth occurs close to the dam it is possible for the algae to be flushed out of the reservoir before reaching large concentrations; however, in 24 out of 38 years flows were less than average and would not be sufficient to flush out the bloom.

The phosphorus loading rate was determined to be the most important single parameter effecting algal growth in both the empirical trophic state models and the simulation model. Blooms could be most effectively reduced by reducing phosphorus input.

Oneida Reservoir Application

The proposed Low Oneida Reservoir, Figure 47, will be a river run reservoir approximately 7 to 9 miles long, narrow, relatively shallow for the first few miles then deeper with an average depth of 81 feet (25 meters). Average annual flow will be about 23 $\times 10^9$ $ft^3 \cdot y^{-1}$ (5.2×10^5 $AF \cdot y^{-1}$). The proposed Low Oneida Reservoir will flood the existing Oneida Reservoir. Limited water quality data are available for the Bear River at Oneida. Field observations indicated the Bear River to be turbid entering the reservoir, but clearing after 3 to 4 miles, as much of suspended material settles out. The extinction coefficient decreased from 2.8 to 1.4 as shown in Table 21. Sampling trips in 1984 to Oneida indicated that the existing reservoir was weakly stratified in May, but did not thermally stratify in the summer. Summer algal blooms were not observed. It is thought that the warm incoming water coupled with the large through flow prevented thermal stratification.

Water Temperature Model

The water temperature model was applied for the months of April through October using average flows for the Bear River at Oneida from Inflow/ Outflow Hydrology of Six Bear River Reservoir Sites (Utah Division of Water Resources 1984). The meteorological data used for the simulation was modified from the meteorological data in Appendix D. The elevation difference between the two sites was used to adjust atmospheric pressure and air temperature. On the average, pressure decreases 1 inch for each 1,000 feet increase in elevation and air temperature decreases 2°C for every 1,000 feet gain.

Figure 48 shows the predicted temperature profiles for the Low Oneida Reservoir during April through October. Figure 49 compares the predicted surface and bottom temperature to the inflow temperature as a function of time over the simulation period. The inflow temperatures appear to be near equilibrium. It can be seen from the figures that no strong temperature gradient forms during the summer months. Surface temperature is only slightly higher than incoming Bear River water and outflowing water temperature is not significantly different from the incoming water temperature. The maximum difference between surface and bottom water is only 3°C. There is not enough of a temperature difference to prevent the reservoir from mixing. The lack of a temperature gradient in such a relatively deep reservoir is due to the large volume of water being withdrawn from the bottom of the reservoir and the warm incoming water.

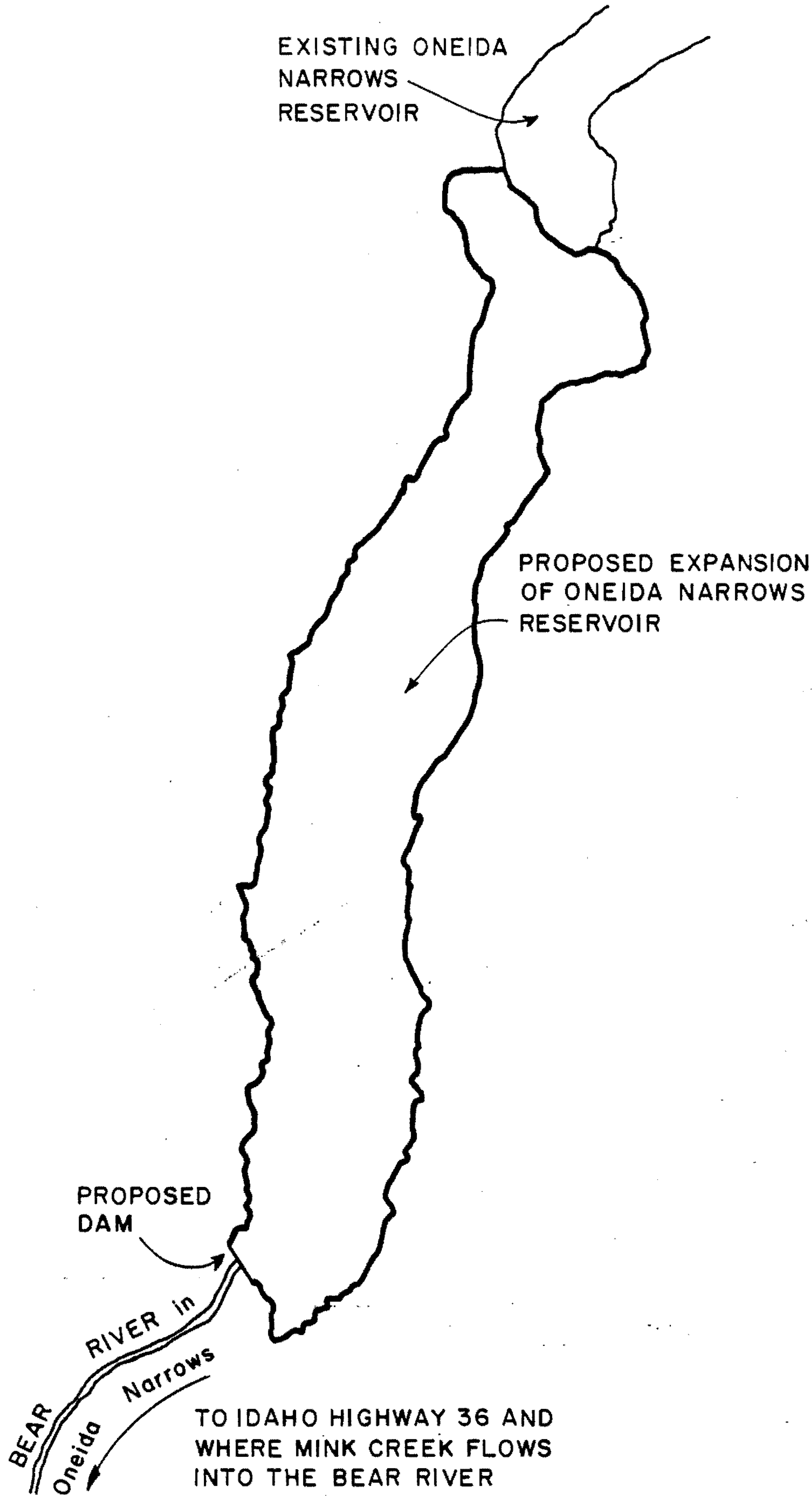


Figure 47. Oneida Reservoir.

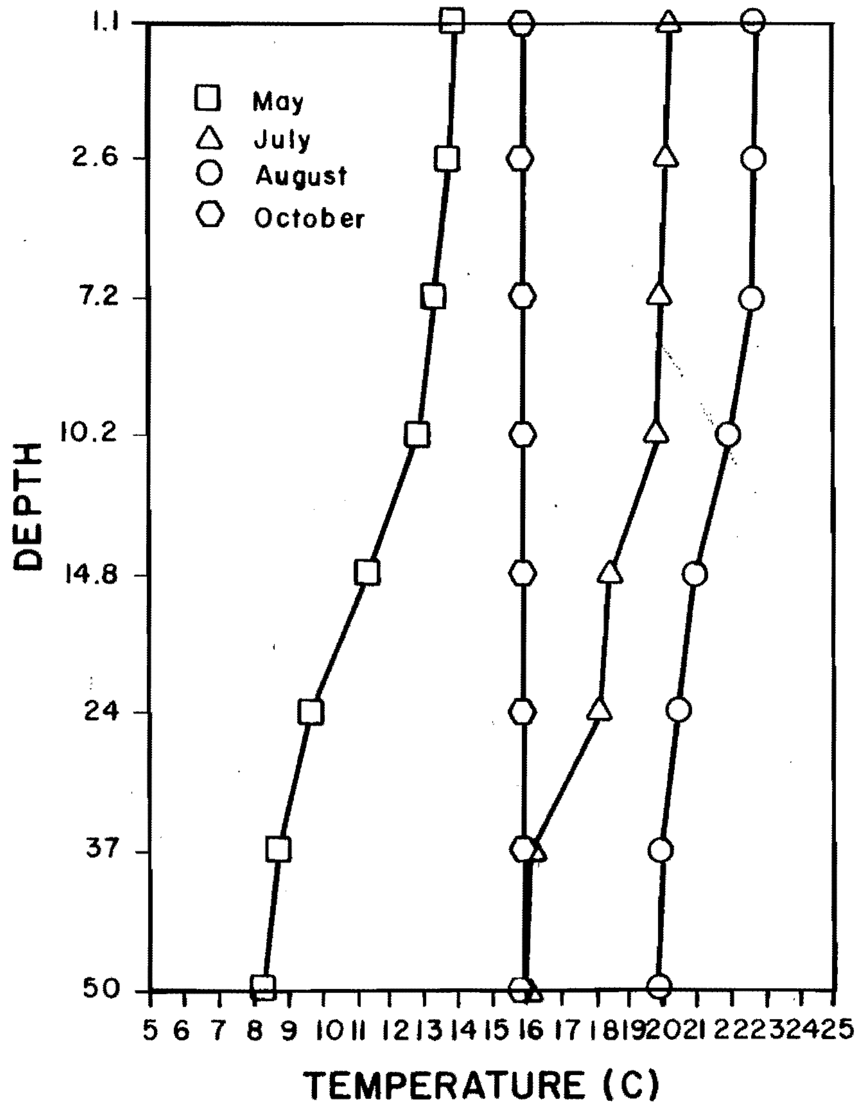


Figure 48. Predicted temperature profile for the Low Oneida Reservoir.

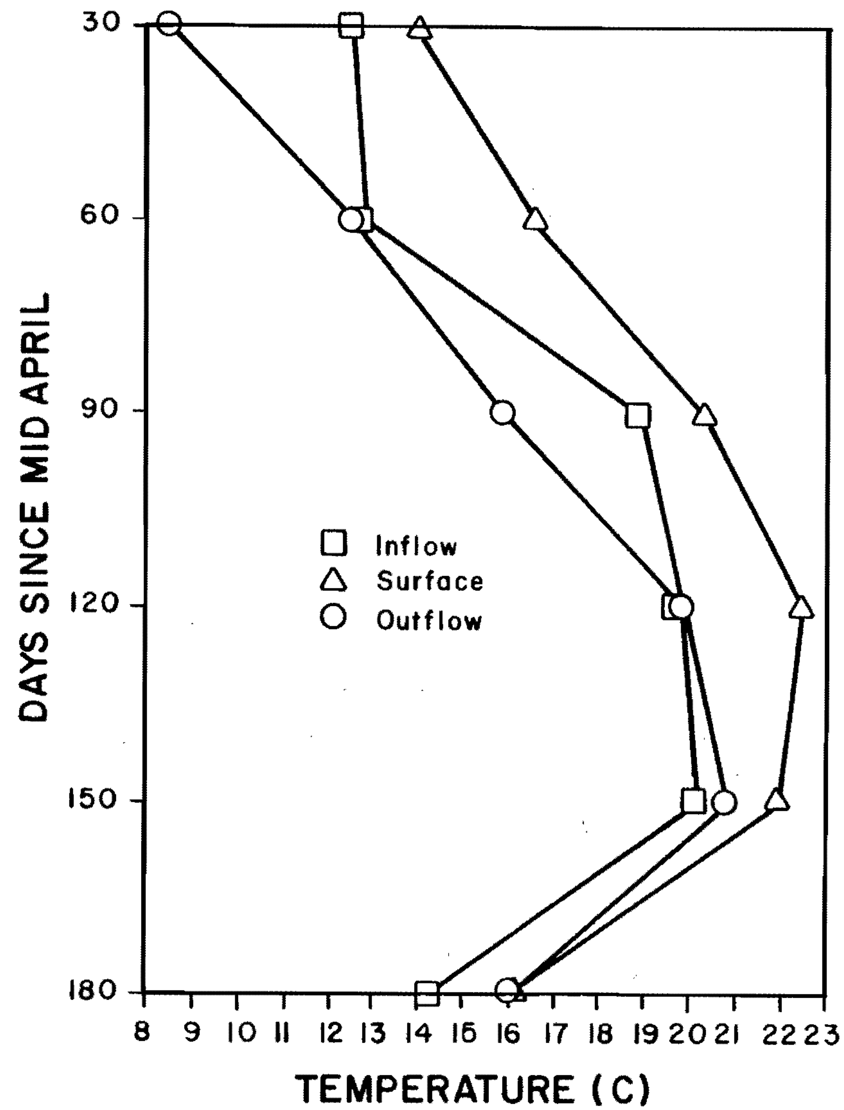


Figure 49. Comparison of inflow, surface, and outflow temperatures of Oneida Reservoir during the simulation period.

Empirical Trophic State Models

The empirical trophic state models were applied to the proposed Low Oneida Reservoir for average flow conditions. Flow, phosphorus concentration data, and results are shown in Table 34.

Predicted average waterbody phosphorus concentrations range from 62 $mg \cdot m^{-3}$ to 102 $mg \cdot m^{-3}$. Using Figure 33A, these values convert to average summer chlorophyll concentrations ranging from 13 to 20 $mg \cdot m^{-3}$. The Jones and Lee model predicts the following average summer parameter values: 1) chlorophyll 15 $mg \cdot m^{-3}$, 2) Secchi depth 1.6 meters, and 3) hypolimnetic oxygen depletion rate of 0.6 $g^2 \cdot m^{-2} \cdot d^{-1}$.

Water Quality Simulation Model

The water quality simulation model, RESEN, was applied to the proposed Low Oneida Reservoir using average flow and an estimated average influent phosphorus concentration. The highest average monthly chlorophyll concentration was 0.9 $mg \cdot m^{-3}$ as shown in Table 26. Figure 50 shows that the simulated chlorophyll concentrations remain low along the length of the proposed Low Oneida Reservoir.

Water Quality Results

The empirical trophic loading models predict average summer chlorophyll concentrations of from 13 to 20 $mg \cdot m^{-3}$ which is much higher than predicted by RESEN, 0.9 $mg \cdot m^{-3}$. The empirical trophic loading models predict eutrophic conditions while RESEN predicts noneutrophic conditions. The results demonstrate the advantage of RESEN to adapt to less than typical conditions. Typically a reservoir as deep as Oneida would stratify and algal blooms would develop because light and nutrient conditions are favorable. But Oneida is not typical, the existing reservoir does not stratify and the temperature model indicates that the proposed reservoir will not develop strong temperature gradients. Algal growth is limited in Oneida Reservoir primarily by the depth of mixing. When the mixed zone is greater than the euphotic zone, algae will spend much of their time in water receiving less light than is needed for growth.

Depth of mixing was determined to be the most important parameter affecting algal growth in Oneida Reservoir. The empirical models suggest that conditions would be favorable for algal blooms if thermal stratification develops.

Additional model runs will be required if more detailed information is desired regarding flows at which Oneida would be expected to stratify.

Mill Creek Reservoir Application

The proposed Mill Creek Reservoir, Figure 51, will be a relatively small deep reservoir approximately 3 miles long with a maximum depth of about 200 feet. Average annual flow will be about 2.7 $x10^9$ $ft^3 \cdot y^{-1}$ (6.2 $x10^4$ $AF \cdot y^{-1}$).

Water Temperature Model

The water temperature model was applied for the months of April through October using average flows for the Blacksmith Fork at Hardware Ranch from Inflow/Outflow Hydrology of Six Bear River Reservoir Sites (Division of Water Resources 1984). The meteorological data used for the simulation are modified from the meteorological data in Appendix D. The elevation difference between the two sites is used to adjust atmospheric pressure and air temperature. On the average, pressure decreases 1 inch for each 1,000 feet increase in elevation and air temperature decreases 2°C for every 1,000 feet gain.

Figure 52 shows the predicted temperature profiles for the Mill Creek Reservoir during April through October. Figure 53 compares the predicted

Table 34. Empirical trophic state model results for the Low Oneida Reservoir assuming average flow conditions.

Approximate Surface Area (ft^2)	4.54 $\times 10^7$
Approximate Volume (ft^3)	3.7 $\times 10^9$
Average Depth (ft)	82
Flow ($ft^3 \cdot y^{-1}$)	23 $\times 10^9$
Hydraulic Residence Time (years)	0.164
Surface Hydraulic Loading (q_s $ft \cdot y^{-1}$)	500
Phosphorus Loading ($mg\ P \cdot m^{-2} \cdot y^{-1}$)	13,738
Average P ($mg \cdot m^{-3}$) (Vollenweider 1975)	64
Average P ($mg \cdot m^{-3}$) (Vollenweider 1976)	85
Average P ($mg \cdot m^{-3}$) (Larson and Mercier 1976)	77
Average P ($mg \cdot m^{-3}$) (Jones and Bachman 1976)	68
Average P ($mg \cdot m^{-3}$) (Kirchner and Dillon 1975)	102
Average P ($mg \cdot m^{-3}$) (Mueller 1982)	62
Jones and Lee (1982)	
Mean Summer Chlorophyll *a* ($mg \cdot m^{-3}$)	14
Mean Summer Secchi Depth (m)	1.6
Hypolimnetic Oxygen Depletion Rate ($g\ O_2 \cdot m^{-2} \cdot d^{-1}$)	0.6
λ	64

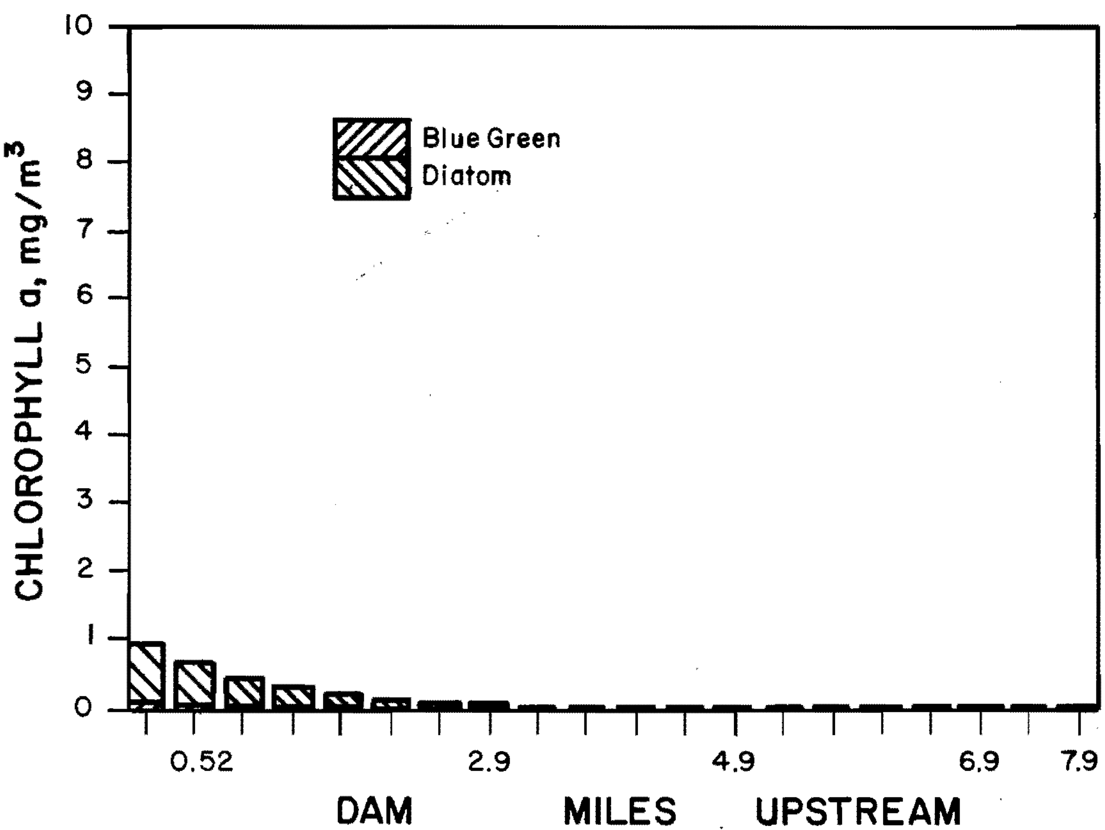


Figure 50. Predicted chlorophyll concentration along the length of Oneida Reservoir.

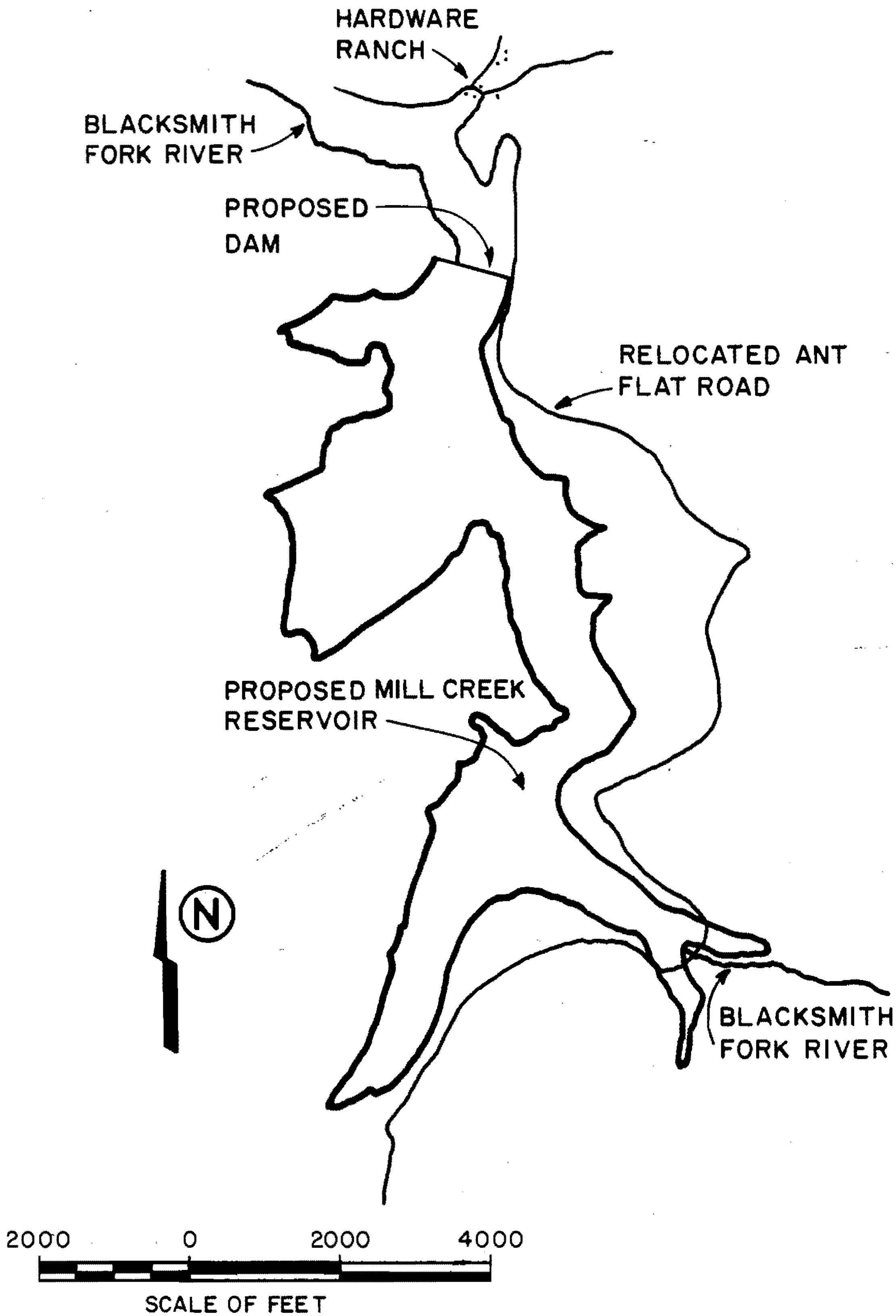


Figure 51. Proposed Mill Creek Reservoir.

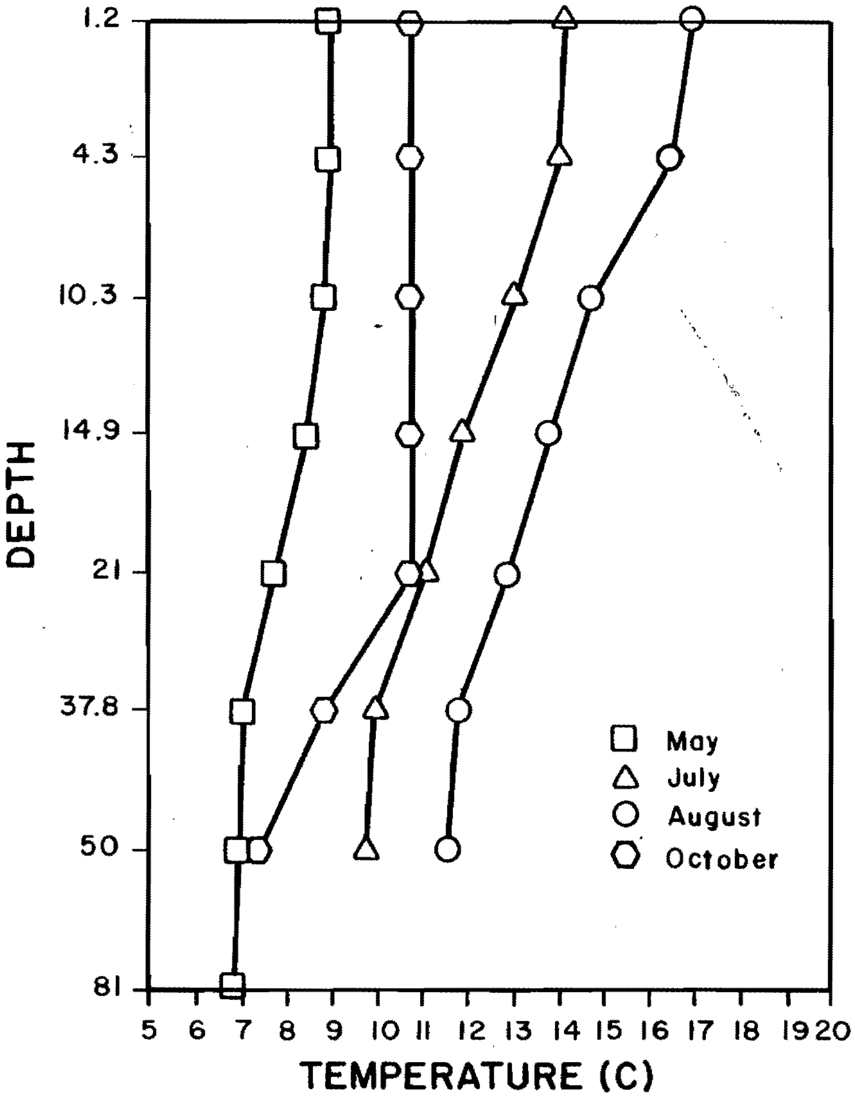


Figure 52. Predicted temperature profiles for Mill Creek Reservoir.

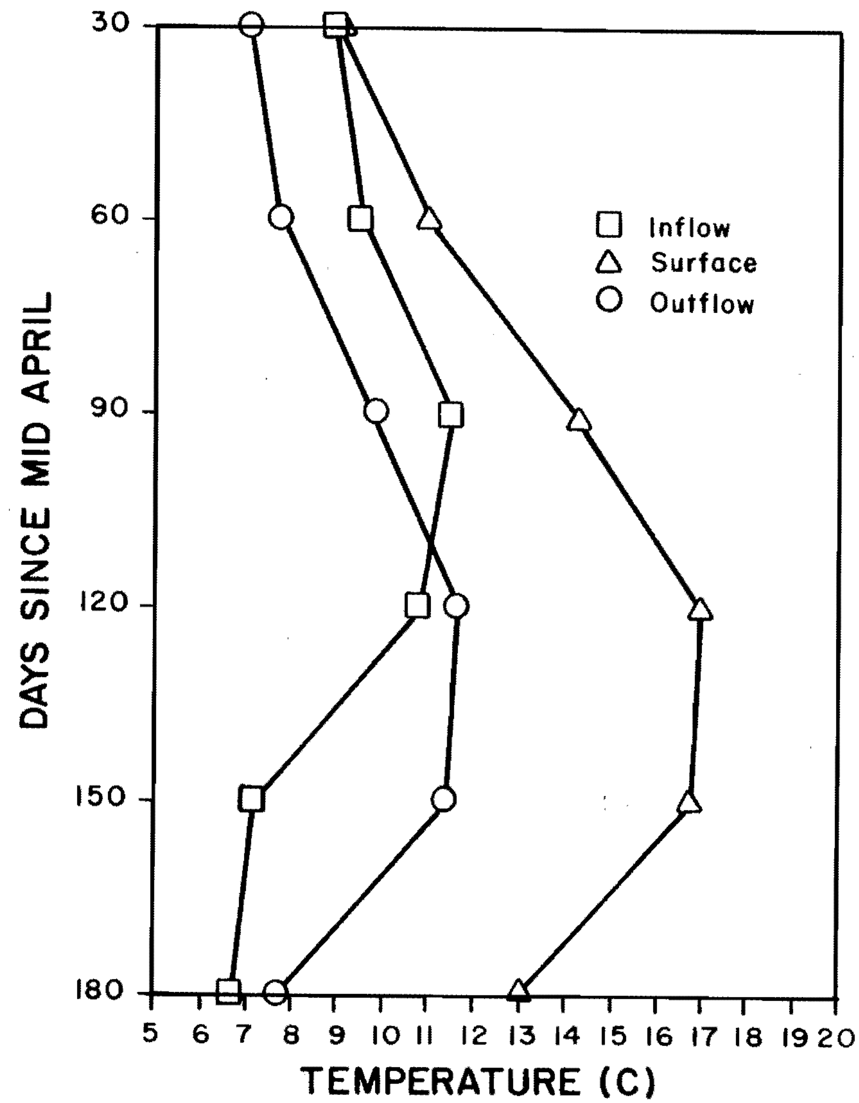


Figure 53. Comparison of inflow, surface, and outflow temperatures during the simulation period for Mill Creek Reservoir.

surface and bottom temperature to the inflow temperature as a function of time over the simulation period. The inflow temperatures are below equilibrium temperature. It can be seen from the figures that a strong temperature gradient forms during the summer months. The maximum difference between surface and bottom water is 5°C. During much of summer inflowing water and outflowing water is from 3 to 7°C colder than surface water. The thermocline remains between 10 meters and 15 meters for the period from May to September.

The predicted temperature stratification is expected to limit algal growth during the summer months. From May to September, incoming water will flow under the hypolimnion preventing nutrient recharge of the upper layer. Algal growth will be limited to nutrients available at the time of stratification.

Empirical Trophic State Models

The empirical trophic state models were applied to the proposed Mill Creek Reservoir for average flow conditions and average phosphorus loads. The phosphorus load used in the models is a rough estimate, a full year's collection of phosphorus and flow data is not available. The phosphorus load is estimated from data collected in the spring of 1985. Flow, phosphorus concentration data, and results are shown in Table 35.

Predicted average waterbody phosphorus concentrations range from 10 $mg \cdot m^{-3}$ to 29 $mg \cdot m^{-3}$. Using Figure 33A, these values convert to average summer chlorophyll concentrations ranging from 2.9 to 7.0 $mg \cdot m^{-3}$. The Jones and Lee model predicts the following average summer parameter values: 1) chlorophyll 3.5 $mg \cdot m^{-3}$, 2) Secchi depth 3.5 meters, and 3) hypolimnetic oxygen depletion rate of 0.3 $g^2 \cdot m^{-2} \cdot d^{-1}$.

Water Quality Simulation Model

The water quality simulation model, RESEN, was applied to the proposed Mill Creek Reservoir using average flow and two estimated influent phosphorus concentrations, one the yearly average available P (4 $\mu g \cdot \ell^{-1}$) and the other the higher spring runoff value (35 $\mu g \cdot \ell^{-1}$). The highest average monthly chlorophyll concentration was 12.0 $mg \cdot m^{-3}$ for the higher P load and 2.4 $mg \cdot m^{-3}$ for lower P load as shown in Table 26. Figure 54 shows the simulated chlorophyll concentration along the length of Mill Creek Reservoir.

Figure 54 shows that chlorophyll concentrations increase rapidly and then decrease. This growth pattern would be possible only in the spring and fall, because for the summer months strong thermal stratification will eliminate plug flow conditions in the photic zone. During the summer the photic zone would be expected to be completely mixed for the entire length of the reservoir. Reducing available phosphorus to 4 $\mu g \cdot \ell^{-1}$ reduces chlorophyll concentrations to less than 2 $mg \cdot m^{-3}$ as shown by the solid line in Figure 54.

Water Quality Results

The empirical trophic loading models predict average summer chlorophyll concentrations of from 2.9 to 7 $mg \cdot m^{-3}$ which is similar to values predicted by RESEN, 4 to 12 $mg \cdot m^{-3}$. The models predict mesotrophic to eutrophic conditions. Stratification of Mill Creek Reservoir will probably limit algal blooms to either the spring or to fall turnover periods. Results from the temperature model and RESEN indicate that during the spring the reservoir is completely mixed with water containing enough phosphorus to support an algal bloom of up to 118 $x10^3$ cells/ml.

Anoxic conditions are not expected to develop in the hypolimnion. The hypolimnion is relatively large, about 40 percent of the reservoir is below the

Table 35. Empirical trophic state model results for Mill Creek Reservoir assuming average flow conditions.

Approximate Surface Area (ft^2)	1.95 x10^7
Approximate Volume (ft^3)	1.22 x10^9
Average Depth (ft)	62.7
Flow ($ft^3 \cdot y^{-1}$)	2.7 x 10^9
Hydraulic Residence Time (years)	0.442
Surface Hydraulic Loading (q_s ft$\cdot y^{-1}$)	140
Phosphorus Loading (mg $P \cdot m^{-2} \cdot y^{-1}$)	884
Average P ($mg \cdot m^{-3}$) (Vollenweider 1975)	12
Average P ($mg \cdot m^{-3}$) (Vollenweider 1976)	17
Average P ($mg \cdot m^{-3}$) (Larson and Mercier 1976)	14
Average P ($mg \cdot m^{-3}$) (Jones and Bachman 1976)	14
Average P ($mg \cdot m^{-3}$) (Kirchner and Dillon 1975)	29
Average P ($mg \cdot m^{-3}$) (Mueller 1982)	10
Jones and Lee (1982)	
Mean Summer Chlorophyll a ($mg \cdot m^{-3}$)	3.5
Mean Summer Secchi Depth (m)	3.5
Hypolimnetic Oxygen Depletion Rate (g $O_2 \cdot m^{-2} \cdot d^{-1}$)	0.3
λ	12

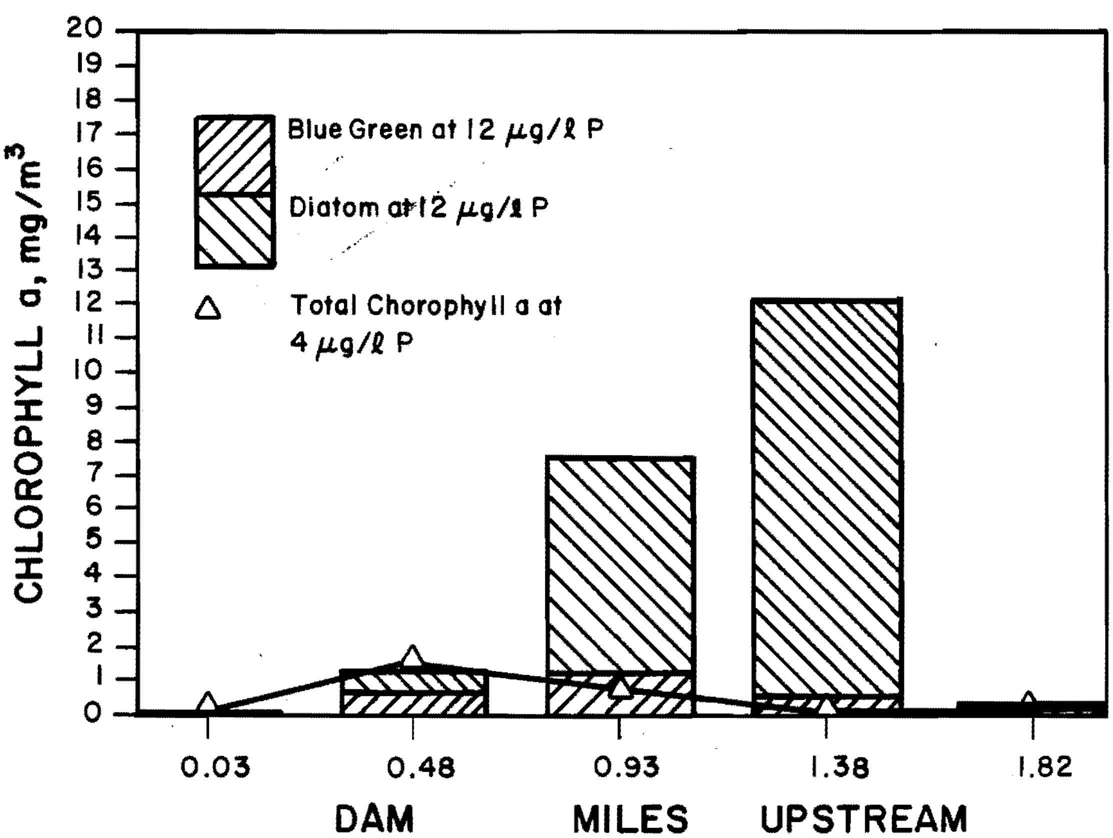


Figure 54. Mill Creek Reservoir predicted algae growth.

thermocline, so there is a large reservoir of oxygen available. Also incoming water is well oxygenated and will flow under the thermocline bringing additional oxygen to the hypolimnion during the summer. Some of the incoming water will mix with warmer levels as the stream enters the reservoir.

The phosphorus loading rate was determined to be the most important single parameter effecting algal growth in both the empirical trophic models and the simulation model. Blooms could be most effectively reduced by reducing phosphorus input.

If more detailed information is desired regarding phosphorus loads and sources of phosphorus loads, then additional field work should be conducted in the proposed Mill Creek Reservoir watershed.

Avon Reservoir Application

The proposed Avon Reservoir, Figure 55, will be a relatively small deep reservoir approximately 2 1/2 miles long with a maximum depth of approximately 180 feet. Average annual flow will be about 1.5 $\times 10^9$ $ft^3 \cdot y^{-1}$ (6.2 $\times$ 10^4 $AF \cdot y^{-1}$).

Water Temperature Model

The water temperature model was applied for the months of April through October using average flows for the South Fork of the Little Bear above Avon from Inflow/Outflow Hydrology of Six Bear River Reservoir Sites (Division of Water Resources 1984). The meteorological data used for the simulation are modified from the meteorological data in Appendix D. The elevation difference between the two sites is used to adjust atmospheric pressure and air temperature. On the average, pressure decreases 1 inch for each 1,000 feet increase in elevation and air temperature decreases 2°C for every 1,000 feet gain.

Figure 56 shows the predicted temperature profiles for the Avon Reservoir during April through October. Figure 57 compares the predicted surface and bottom temperature to the inflow temperature as a function of time over the simulation period. The inflow temperatures are below equilibrium temperature. It can be seen from the figures that a strong temperature gradient forms during the summer months. The maximum difference between surface and bottom water is 8°C. During much of summer inflowing water and outflowing water is from 5 to 8°C colder than surface water. The thermocline remains between 12 and 16 meters for the period from May to September. During this period, most of the nutrients in the incoming water would pass under the eutrophic zone and thus not be available for maintaining algal growth.

Empirical Trophic State Models

The empirical trophic state models were applied to the proposed Avon Reservoir for average flow conditions and average phosphorus loads. The phosphorus load used in the models is just a rough estimate, a full year's collection of phosphorus and flow data was not available. The phosphorus load is estimated from data collected in the Spring of 1985. Flow, phosphorus concentration data, and results are shown in Table 36.

Predicted average waterbody phosphorus concentrations range from 29 $mg \cdot m^{-3}$ to 88 $mg \cdot m^{-3}$. Using Figure 33A, these values convert to average summer chlorophyll concentrations ranging from 7.0 to 17.6 $mg \cdot m^{-3}$. The Jones and Lee model predicts the following average summer parameter values: 1) chlorophyll 8.6 $mg \cdot m^{-3}$, 2) Secchi depth 2.5 meters, and 3) hypolimnetic oxygen depletion rate of 0.5 $g^2 \cdot m^{-2} \cdot d^{-1}$.

Water Quality Simulation Model

The water quality simulation model, RESEN, was applied to the proposed Avon

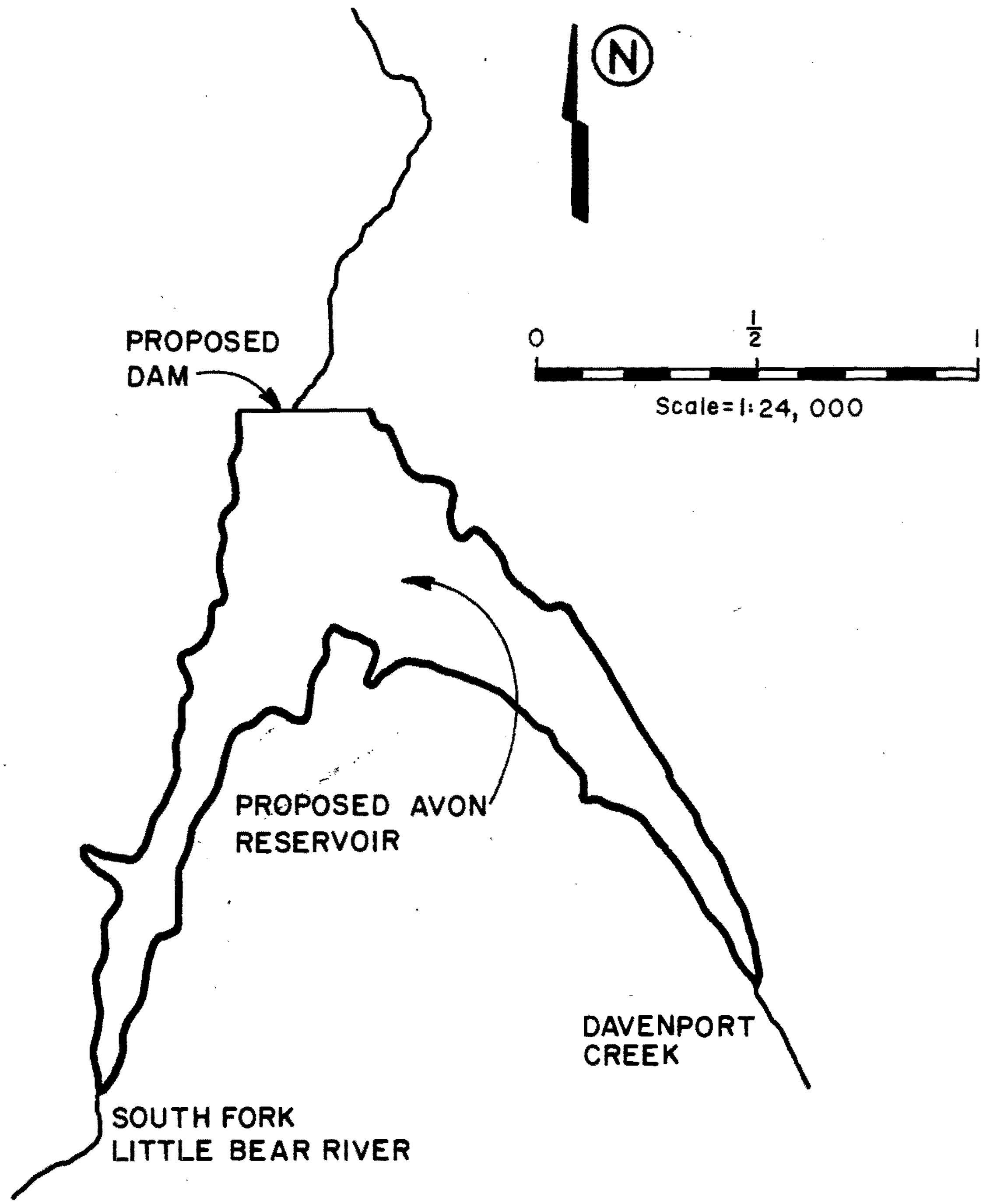


Figure 55. Proposed Avon Reservoir.

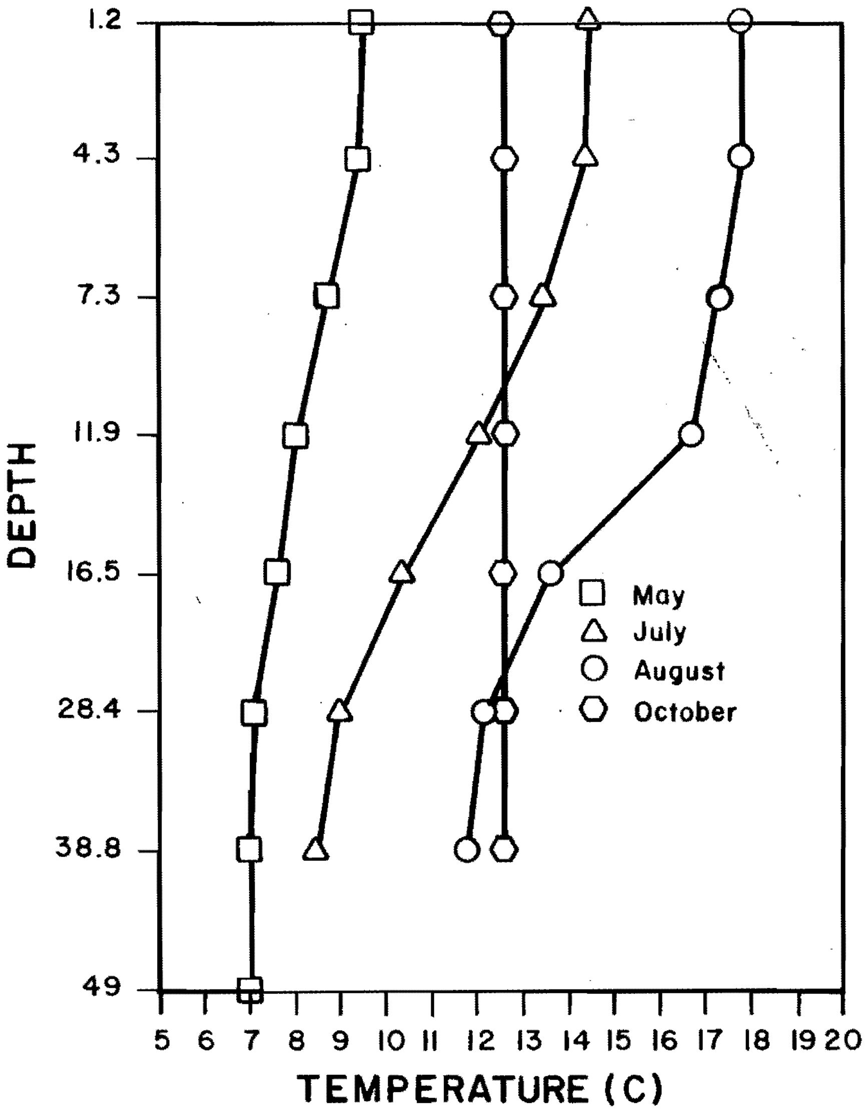


Figure 56. Simulated temperature profiles for the proposed Avon Reservoir.

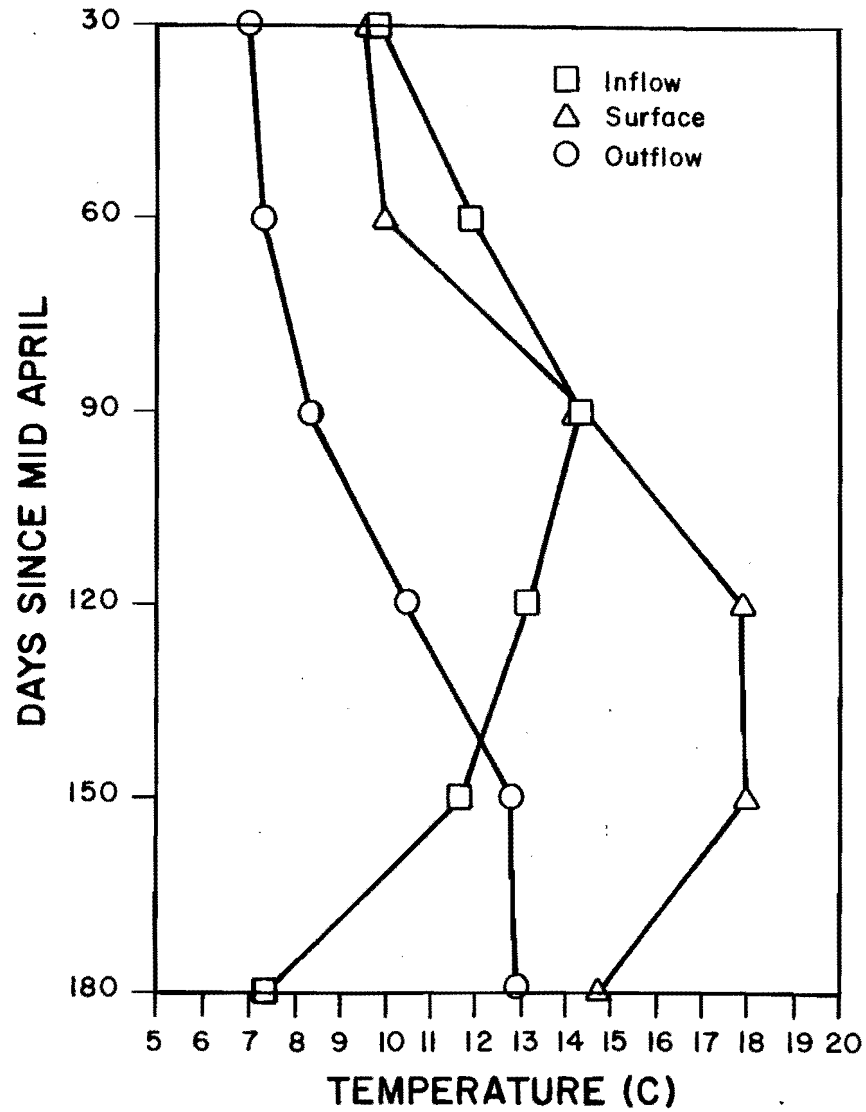


Figure 57. Comparison of inflow, surface, and outflow temperatures during the simulation period for the Avon Reservoir.

Table 36. Empirical trophic state model results for Avon Reservoir assuming average flow conditions.

Approximate Surface Area (ft^2)	12.7×10^7
Approximate Volume (ft^3)	7.8×10^8
Average Depth (ft)	61
Flow ($ft^3 \cdot y^{-1}$)	1.5×10^9
Hydraulic Residence Time (years)	0.510
Surface Hydraulic Loading (q_s $ft \cdot y^{-1}$)	37
Phosphorus Loading ($mg\ P \cdot m^{-2} \cdot y^{-1}$)	2317
Average P ($mg \cdot m^{-3}$) (Vollenweider 1975)	37
Average P ($mg \cdot m^{-3}$) (Vollenweider 1976)	50
Average P ($mg \cdot m^{-3}$) (Larson and Mercier 1976)	42
Average P ($mg \cdot m^{-3}$) (Jones and Bachman 1976)	40
Average P ($mg \cdot m^{-3}$) (Kirchner and Dillon 1975)	88
Average P ($mg \cdot m^{-3}$) (Mueller 1982)	29
Jones and Lee (1982)	
Mean Summer Chlorophyll _a_ ($mg \cdot m^{-3}$)	8.6
Mean Summer Secchi Depth (m)	2.5
Hypolimnetic Oxygen Depletion Rate ($g\ O_2 \cdot m^{-2} \cdot d^{-1}$)	0.5
λ	37

Reservoir using average flow and two estimated influent phosphorus concentrations, one the yearly average available P ($12.6\ \mu g \cdot \ell^{-1}$) and the other the higher spring runoff value ($49\ \mu g \cdot \ell^{-1}$). The highest average monthly chlorophyll concentration was $16.8\ mg \cdot m^{-3}$ for the higher P load and $7.1\ mg \cdot m^{-3}$ for lower P load as shown in Table 26. Figure 58 shows the simulated chlorophyll concentrations along the length of Avon Reservoir. Chlorophyll concentration increases and then decreases rapidly toward the dam.

Water Quality Results

The empirical trophic loading models predict average summer chlorophyll concentrations of from 7.0 to 17.6 $mg \cdot m^{-3}$ which is similar to values predicted by RESEN. The models predict mesotrophic to eutrophic conditions for Avon Reservoir. Stratification of Avon Reservoir will probably limit algal blooms to either the spring or to fall turnover periods. Results from the temperature model and RESEN indicate that during the spring the reservoir is completely mixed with water containing enough phosphorus to support an algal bloom of up to 278×10^3 $cells \cdot m\ell^{-1}$. As with Mill Creek Reservoir, the plug flow conditions shown in Figure 58 would exist only in the spring and fall.

Anoxic conditions are not expected to develop in the hypolimnion. The hypolimnion is relatively large, with about 40 percent of the reservoir below the thermocline, so there is a large reservoir of oxygen available. Also incoming water is well oxygenated and will flow under the thermocline bringing additional oxygen to the hypolimnion during the summer. Some of the incoming water will mix with warmer levels as the stream enters the reservoir.

The phosphorus loading rate was determined to be the most important single parameter effecting algal growth in both the empirical trophic models and the simulation model. Blooms could be most effectively reduced by reducing phosphorus input.

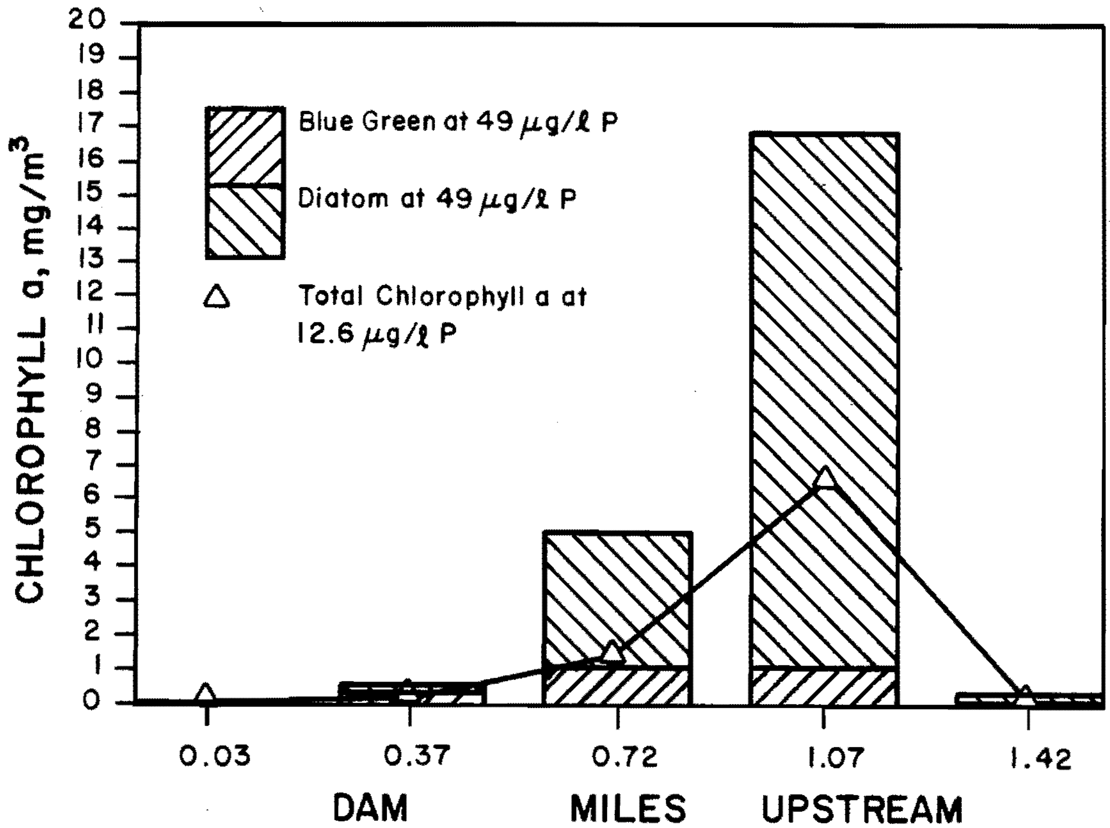


Figure 58. Simulated algae growth along the length of the proposed Avon Reservoir.

If more detailed information is desired regarding phosphorus loads and sources of phosphorus loads, then additional field work should be conducted in the Avon Reservoir watershed. Additional data would be necessary before doing an in-depth model study of Avon Reservoir.

LIMNOLOGICAL COMPARISON OF RESERVOIRS

Table 37 presents a comparison of the existing Oneida and Hyrum Reservoirs with the proposed Amalga, Avon, Mill Creek, Oneida, and Honeyville Reservoirs. Although smaller in size, Hyrum Reservoir is limnologically more similar to the proposed reservoirs than is Oneida Reservoir. The very short hydraulic residence time in Oneida observed during 1984 prevents stratification and limits the development of large algal populations. Mill Creek and Avon have much longer residence times than the other reservoirs.

Implication of Upstream Reservoir on Water Quality in Honeyville Reservoir

One of the major questions to be answered by this report is the expected impact of the upstream reservoirs on water quality in Honeyville Reservoir. Upstream reservoirs have been noted to remove sediment and phosphorus thus improving downstream water quality. Unfortunately, the proposed reservoirs will not improve water quality significantly on the Bear River. Oneida presently removes sediment and phosphorus associated with the sediment from the Bear River, but the scant evidence available and model results indicate little change in phosphorus concentration above and below Oneida. Even if Oneida could remove a significant portion of incoming phosphorus, water quality would only improve for a short distance downstream, for there are many sources of phosphorus downstream of Oneida which would continue to add phosphorus to the Bear River. Mill Creek and Avon Reservoirs are expected to have no noticeable impact on water quality of Honeyville Reservoir. They are too far upstream with too many sources of sediment and phosphorus between them and Honeyville to have any impact on water quality at Honeyville. In addition, Avon and Mill Creek will not be effective phosphorus traps because of large withdrawal from the hypolimnion.

Only the proposed Amalga Reservoir is close enough to the proposed Honeyville Reservoir to potentially have any impact on water quality there, but the models indicate that Amalga Reservoir will be an inefficient sediment and phosphorus trap. Even if results had indicated Amalga could function as a nutrient trap, nutrient release from Cutler Reservoir would likely cause downstream water quality problems for an indeterminate period of time.

Unfortunately improvements in water quality of the lower Bear River can only be achieved by control of phosphorus and sediment sources. Additional studies would be needed to identify the sources of phosphorus before any control measures could be designed.

Table 37. Limnological comparison of Hyrum, Oneida (existing), and the proposed Amalga, Honeyville, Millcreek, Avon, and Oneida Reservoirs.

Reservoir	Inflow (m^3/s)	Average Depth (m)	Surface Area (m^2)	Volume (m^3)	Hydraulic Residence Time (days)	Average Temperature (°C)	Depth to Thermocline (m)	Degree of Stratification (Δ Temp, °C)	Transparency (Secchi, m)	Total Phosphorus (μg/l)	Ortho-phosphorus (μg/l)	Nitrate-Nitrogen (μg/l)	Maximum Chlorophyll a (μg/l)	Maximum Algae Cells (#/ml)
Hyrum (High Flow)	4.2	20.4	1.9×10^{6}	1.9×10^{7}	52	17.8	15	1	2.2	134	33	532	9.6	5.6×10^{3} [1]
Hyrum (Low Flow)	1.8	20.4	1.9×10^{6}	1.9×10^{7}	123	17.1	9.5	12	2.7	57	21	453	102	3.2×10^{5} [1]
Oneida (Summer 1984)		11.0			1.5	19.1	**	NA	0.6	65	17	458		
Amalga (Average Flow)*	18.0	3.2	2.3×10^{7}	7.5×10^{7}	48	20	**	NA	1.6	185	90			
Honeyville (Average Flow)	30.5	9.8	1.5×10^{7}	1.5×10^{8}	58	18.7	11	11	1.6	118	54			
Oneida (Average Flow)	20.4	25	4.2×10^{6}	1.1×10^{8}	59	22	**	NA	1.6	90	41		0.9	9×10^{3} [2]
Millcreek	2.4	19	1.8×10^{6}	3.5×10^{7}	163	17	15	5	3.5	100-21	35-4.2		12-4	118×10^{3}-24×10^{3} [2]
Avon	1.4	18	1.2×10^{6}	2.2×10^{7}	186	17	12	6	2.5	305-63	49-12.6		16.8-7.1	278×10^{3}-62×10^{3} [2]

*Flow data is average June through October 1979. Thermal, transparency, phosphorus, chlorophyll a, and algae data are from simulation.
**Thermocline not formed.
NA = Not applicable.
[1] From Drury 1975.
[2] From RESEN.

WATER TREATMENT COSTS

Introduction

The principal reason for treating drinking water is to remove pathogens and toxic materials. In addition, water treatment strives to produce water that is aesthetically acceptable to the consumer through removal of turbidity, suspended solids, color, taste, and odor, and may also remove hardness. Pathogens are removed through physical trapping and inactivated by chemical means in most treatment schemes. In Utah, conventional water treatment is defined as coagulation, flocculation, sedimentation, filtration, and disinfection. In conventional water treatment, suspended solids including microorganisms and cysts and eggs of higher parasites are trapped in a chemical floc and removed through sedimentation. Pathogens not removed in coagulation/flocculation and sedimentation may be trapped in rapid sand filters through which the treated water is passed next. Prior to distribution, the filtered water is treated with chlorine which chemically oxidizes vital components of any surviving pathogens and kills them or makes them unable to initiate infection.

The processes of coagulation/flocculation/sedimentation and rapid sand filtration remove suspended solids from the water and provide a means by which it may be clarified. In addition, some color, taste, and odor components of the water may be removed. Many potentially toxic metals are removed and some toxic organic compounds may also be reduced in concentration by these processes (Cumerman et al. 1979). Where turbidity and low to moderate concentrations of indicator bacteria (total and fecal coliforms) are the only raw water contaminants of concern, conventional treatment is adequate. When taste and odor problems are in excess of the removal capability of conventional treatment, a chemical oxidant such as potassium permanganate ($KMnO_4$) is often added to oxidize the organic compounds which cause this problem. When toxic materials occur in the raw water, appropriate removal processes must be added to the treatment scheme.

When water is chlorinated for disinfection, chlorinated organic compounds are formed through reactions with organic matter in the water. The public health effects of these reaction products is still being studied, but one group of these compounds, the trihalomethanes (THMs), have been linked to an elevated incidence of cancer in communities where water supplies contain elevated concentrations of these compounds. The most common trihalomethane (THM), chloroform, is a proven carcinogen (Cotruvo and Wu 1978). Federal regulations limit the total THM concentration in drinking water supplies serving more than 10,000 people to 100 $\mu g \cdot \ell^{-1}$ (Federal Register 1979, 1980). High THM levels are often associated with water supplies drawn from eutrophic reservoirs (Jones and Lee 1982a). Water treatment plants in Salt Lake County which use reservoir water have higher average total THM concentrations than those using stream water (Peters et al. 1981, Cook et al. 1982). If the eutrophic conditions occur for the proposed Honeyville Reservoir as projected by the modeling efforts reported here, techniques for controlling trihalomethanes in the treated water from this reservoir may be required.

Controlling trihalomethanes requires the addition of another unit process to a conventional treatment plant to either remove THM precursor compounds prior to chlorination, or to remove the THMs after formation. A portion of the precursor concentration can be eliminated through oxidation with $KMnO_4$, or the precursors can be adsorbed onto granular or powdered activated carbon. Once formed, THMs can be removed from water using aeration with diffused air or mechanical mixing because of their volatile nature. Granular or powdered activated carbon can also be used to adsorb these compounds.

Costs

The State of Utah Public Drinking Water Regulations (State of Utah Department of Health 1984) mandate minimum treatment of surface drinking water supplies with flash mixing of coagulant chemicals, flocculation, sedimentation, filtration, and disinfection. This treatment is called "conventional complete treatment." Conventional water treatment plants are sized primarily for the volume of water to be treated, and capital, labor, energy, and maintenance materials costs are generally independent of raw water quality. Poor raw water quality increases these costs when extra unit processes must be added to remove toxic chemicals or exceptionally high concentrations of pathogens or indicator organisms. The annual costs for capital, labor, energy, and maintenance for a typical conventional 100 MGD plant treating surface water in the U.S. in 1985 was estimated to be $73.32 per acre ft. This cost includes amortized construction capital at 10 percent interest for 20 years, labor at $14.00 per hour, electricity at $0.05 per kwh, fuel at $1.00 per gallon, and maintenance materials, but does not include chemicals. The 100 MGD annual cost was derived by updating the 40 MGD and 130 MGD plant cost estimates for 1978 presented by Cumerman et al. (1979). This was done using the Engineering News Report Cost Construction Index of September 12, 1985, and the August 1985, Producer Price Index for Finished Goods as prescribed by Cumerman et al. (1979), and by making a linear extrapolation between these updated costs to the 100 MGD value.

Assuming that chemical costs could be best estimated from a plant treating water of similar quality to that anticipated in the proposed Honeyville Reservoir, chemical use of the Little Cottonwood Metropolitan District Water Treatment Plant as a function of raw water quality was investigated using multiple regression analysis. No reliable correlation could be found ($r^2 = 0.25$, $n = 41$) between raw water turbidity, color, odor, temperature, or month of the year from January 1982 to August 1985 and the use of coagulation/flocculation chemicals (alum, lime, and flocculation aid) per acre ft of water treated. There was some tendency for use of coagulation/flocculation chemicals to be higher during summer and fall months when withdrawals from Deer Creek Reservoir are highest, but this pattern was not statistically significant. Chlorine usage was apparently independent of raw water turbidity, color, odor, and temperature, and month of the year. The use of permanganate was correlated to the interaction between odor and turbidity, and use of permanganate increased with month of the year as described by the following relationship:

$$\text{Permanganate costs, \$} = 0.018 \text{ (turbidity x odor)} + 0.047 \text{ (month)} + 0.008$$

$$(r^2 = 0.703, n = 44)$$

where the months of the year are numbered 1 through 12 for January through December, respectively. This rather complex relationship indicates that odor measurements alone do not dictate permanganate use, and suggests that operator perception of raw water quality (turbidity) and operator experience with times of the year when problems occur (month) significantly modify the rate of permanganate usage. Apparently, raw water odor is above acceptable levels at the Little Cottonwood Plant in the summer during algae blooms in Deer Creek Reservoir and in the late fall when thermal stratification in the reservoir breaks down and hypolimnetic waters are mixed throughout the water column. Similar odor problems may develop in the Honeyville Reservoir if the reservoir becomes eutrophic.

Possible chemical costs for conventional and odor control treatment of Bear River water, based on chemical costs for water treatment at the Little Cottonwood Metropolitan District Water Treatment Plant are summarized in Table 38. The Little Cottonwood Plant treated 15.2 MGD in January and 82.3 MGD in July of 1985. Chemical costs may add from $4 to $10 per acre ft for conventional treatment assuming that the proposed treatment plant is operated similarly to the Little Cottonwood Plant.

Total conventional treatment costs for Bear River water per acre ft are anticipated to be approximately:

Nonchemical costs	$73	(adapted from Cumerman et al. 1979)
Chemical costs:	7	(Table 38)
Total	$80	

If trihalomethane formation becomes excessive, the addition of unit processes to control precursors or to remove the THMs will add substantially to water treatment costs. From data given by Symons et al. (1981) for a 100 MGD plant, THM control costs could range from approximately $6 to nearly $190 per acre ft depending on the removal option chosen and the magnitude of THM removal required (Table 39). If THM concentrations must be reduced by more than 20 percent in order to meet drinking water standards, treatment costs increase substantially.

Table 38. Possible chemical costs for conventional and taste and odor treatment of Bear River water.

Chemical Unit Process	Costs ($/acre-ft) Average	Standard Deviation	Range
Coagulation/Flocculation	6.77	1.21	3.60-9.48
Taste and Odor Control	0.50	0.46	0-1.79
Chlorination	0.45	0.12	0.02-0.83
Total	7.72	1.41	3.62-10.47

Table 39. Estimated trihalomethane (THM) control costs (Symons et al. 1981).*

Unit Process	Costs ($/acre-ft) Percent Removal 20	50	80
THM Precursor Control with:			
$KMnO_4$	32.07	-	-
Granular Activated Carbon	23.44	57.36	91.28
Powdered Activated Carbon	8.51	96.77	185.02
THM Removal with:			
Aeration (Diffused Air)	5.92	25.78	45.64
Granular Activated Carbon	19.74	35.78	51.81
Powdered Activated Carbon	9.13	68.09	127.05

*Costs are estimated for a plant of 100 MGD capacity treating surface water.

CONCLUSIONS

The following conclusions have been reached from the studies reported here:

1. Previous studies of Bear River water quality have identified high concentrations of fecal indicator bacteria, BOD_5 concentrations, TDS concentrations, and phosphorus concentrations to be occasionally in excess of desirable use standards.

2. Although NO_3-N concentrations near to or in excess of drinking water standards were identified in one previous study, NO_3-N concentration data from historical data and data collected during the present study did not indicate that NO_3-N concentrations approach the 10 $mg \cdot \ell^{-1}$ standard in the Bear River or its tributaries.

3. Historical and current data indicate that the Cub River has been a significant source of pollutants, both chemical and microbiological, to the Bear River. High phosphorus loads from the Cub River may enhance eutrophication in the lower portion of the proposed Amalga Reservoir.

4. Water quality monitoring during the present study found the lower reaches of the Little Bear River occasionally accumulate undesirable concentrations of BOD, NH_3-N, NO_3-N, PO_4-P, and total and fecal coliforms.

5. Oneida Reservoir has a relatively short hydraulic retention time, does not develop stable thermal stratification throughout most of the reservoir during summer months, and is probably not a good model for the proposed Bear River reservoirs.

6. Cutler Reservoir is very shallow and behaves physically like a slow moving river. The backwaters are marshy and support large populations of waterfowl which may contribute substantially to the fecal indicator load of the river.

7. The possible impact of saline and phosphorus rich waters in the Barrens marsh on the water quality of the proposed Barrens portion of the Amalga Reservoir needs to be investigated.

8. High suspended solids and phosphorus loads to the Bear River from erosion in the Weston Creek, Fivemile Creek, and Deep Creek watersheds contribute significantly to the eutrophication potential of the proposed Amalga Reservoir and possibly the Honeyville Reservoir.

9. Phosphorus loads in streams that will feed the proposed Mill Creek and Avon Reservoirs are most important during spring runoff and appear to be associated with erosion.

10. Settling characteristics of turbidity in a sample of Bear River water suggest that the proposed reservoirs will remove over 90 percent of the turbidity in the water. The increased clarity of the water may encourage algal production in the reservoirs.

11. Because of high phosphorus loading, the proposed Amalga Reservoir is likely to become very eutrophic near the dam and in the Cub River branch if turbidity decreases over the length of the reservoir.

12. Eutrophic conditions are likely to develop near the dam in the Honeyville Reservoir if turbidity decreases over the length of the reservoir and zooplankton grazing is negligible. If high populations of zooplankton develop, conditions will improve to mesotrophic to eutrophic status.

13. The proposed Low Oneida Reservoir is not expected to develop strong thermal stratification, and oligotrophic conditions are anticipated due to the depth of mixing in the water column.

14. Algal blooms resulting in mesotrophic to eutrophic conditions in the spring and fall are expected to develop in the proposed Mill Creek Reservoir.

15. The proposed Avon Reservoir will have water quality similar to the Mill Creek Reservoir and will probably produce spring and fall algal blooms resulting in mesotrophic to eutrophic conditions during these blooms.

16. Phosphorus inputs from tributaries and nonpoint sources in river reaches below the proposed reservoirs will probably negate the phosphorus removal achieved by these reservoirs.

17. Costs for conventional drinking water treatment for Bear River water in 1985 would be approximately $80 per acre ft. Taste and odor control would add to these costs.

18. If trihalomethane formation during water treatment exceeds drinking water standards, treatment costs would increase by $6 to $190 per acre ft depending on the degree of trihalomethane removal required and the treatment method selected.

LITERATURE CITED

ASCE. 1977. Sedimentation engineering. Vito A. Vanoni, Editor. American Society of Civil Engineers, New York, 745 p.

BWR (Board of Water Resources). 1982. Cache Valley preliminary feasibility study. Utah Department of Natural Resources Division of Water Resources, Salt Lake City, UT.

Bisson, J. W., and V. J. Cabelli. 1980. Clostridium perfringens as a water pollution indicator. J. Wat. Poll. Cont. Fed. 52:241-248.

Caupp, Craig L., and William J. Grenney. 1982. Reservoir destratification by withdrawal from the hypolimnion. Proceedings of the Third International Conference on State in Ecological Modelling. Colorado State University. pp. 649-654.

Cook, K. R., V. D. Adams, V. A. Lamarra, D. B. George, and R. A. Hanson. 1982. Trihalomethane compounds and their precursors in Salt Lake County. Utah Water Research Laboratory, Utah State University, Logan, UT. 125 p.

Cotruvo, J. A., and C. Wu. 1978. Controlling organics: Why now? Jour. Amer. Wat. Works Assn. 70:590-594.

Cumerman, R. C., R. L. Culp, and S. P. Hansen. 1979. Estimating water treatment costs. Vol. 1. Summary. EPA-600/2-79-162a. U.S. Environmental Protection Agency, Cincinnati, OH. 99 p.

Dillion, P. J., and F. H. Rigler. 1974. The phosphorus-chlorophyll relationship in lakes. Limnol. Oceanogr. 19:767-773.

Drury, D. D. 1975. The effects of artificial destratification on the water quality and microbial populations of Hyrum Reservoir. PhD dissertation. Utah State University, Logan, UT.

Drury, D. D., D. B. Porcella, and R. A. Gearheart. 1975. The effects of artificial destratification on the water quality and microbial populations in Hyrum Reservoir. PRJEW011-1. Utah Water Research Laboratory, Utah State University, Logan, UT.

Environmental Protection Agency. 1978. Rates, constants and kinetics formulation in surface water quality modeling. EPA-600/3-78-105. Environmental Research Laboratory, Athens, Georgia.

Federal Register. 1979. Interim primary drinking water regulations: Control of trihalomethanes in drinking water. 44:68624-68707.

Federal Register. 1980. Interim primary drinking water regulations: Control of trihalomethanes in drinking water. 45:15542-15547.

Grenney, W. J., and A. K. Kraszewski. 1981. Description and application of the stream simulation and assessment model: Version IV. FWS/OBS-81/46. USDI, Fish and Wildlife Service, Fort Collins, CO. 199 p.

Grenney, W. J., J. J. Messer, and J. Ho. 1981. Eutrophication potential for the proposed Taylor Draw Reservoir. Final Report to Western Engineers, Grand Junction, CO. 109 p.

Haws, F. W., and T. C. Hughes. 1973. Hydrologic inventory of the Bear River study unit. PRWG40-8. Utah Water Research Laboratory, Utah State University, Logan, UT.

HEC. 1978. Water quality for river-reservoir systems. Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, CA. 279 p.

Israelsen, E. K., D. R. Bernard, T. M. Twedt, and H. M. Runke. 1975. A technique for predicting the aquatic ecosystem response to weather modification. PRWG138-1. Utah Water Research Laboratory, Utah State University, Logan, UT.

Jones, J. R., and R. W. Bachman. 1976. Phosphorus removal by sedimentation in some Iowa reservoirs. Verh. Internat. Verein. Limnol. 20:1576-1580.

Jones, R. Anne, and G. Fred Lee. 1982a. Chlorophyll--a raw water quality parameter. Journal AWWA Research and Technology. pp. 490-496.

Jones, R. Anne, and G. Fred Lee. 1982b. Recent advances in assessing impact of phosphorus loads on eutrophication-related water quality. Water Research 16:503-515.

Kalff, J., and R. Knoechel. 1978. Phytoplankton and their dynamics in oligotrophic and eutrophic lakes. Ann. Rev. Ecol. Syst. 9:475-495.

Kirchner, W., and P. Dillon. 1975. An empirical method of estimating the retention of phosphorus in lakes. Water Res. Research 2:182-187.

Krenkel, P., and V. Novotny. 1980. Water quality management. Academic Press, New York.

Larsen, D. P., and H. T. Mercier. 1976. Phosphorus retention capacity of lakes. J. Fish. Res. Bd. Can. 33:1742-1750.

Luce, W. A. 1974. Phosphorus budget of the Hyrum Reservoir-Little Bear River system. MS Thesis, Utah State University, Logan, UT.

MacKenthun, K. M., and L. E. Kenp. 1970. Biological problems encountered in water supplies. Journal AWWA 62(8):520.

Messer, J. 1983. Reconnaissance of projected trophic states of four proposed reservoirs in the Bear River Basin. Twelve-Nine, Inc., Logan, UT.

Messer, J. J., W. J. Grenney, and J. Ho. 1982. Simulation of phytoplankton growth in small, fast-flushing reservoirs: Eutrophication management implications. Proceedings of the Third International Conference on State in Ecological Modelling. Colorado State University. pp. 787-801.

Messer, J. J., E. K. Israelsen, and V. D. Adams. 1981. Natural salinity removal processes in reservoirs. Q-81/03. Utah Water Research Laboratory, Utah State University, Logan, UT.

Metcalf and Eddy, Inc. 1979. Wastewater engineering: Treatment, disposal, reuse. McGraw-Hill Book Co., New York, NY. 920 p.

Miller, W. E., J. C. Greene, and T. Shiroyama. 1978. The Selenastrum capricornutm Printz algal assay bottle test. EPA-600/9-78-018, Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, OR.

Mueller, D. K. 1982. Mass balance model estimation of phosphorus concentration in reservoirs. Water Res. Bull. 18:377-382.

Peters, T., V. D. Adams, and D. B. George. 1981. The occurrence of trihalomethane compounds in Salt Lake City and Ogden, Utah, drinking water supplies. UWRL/Q-81/05. Utah Water Research Laboratory, Utah State University, Logan, UT. 61 p.

Rast, W., and G. F. Lee. 1978. Summary analysis of the North American (U.S. portion) OECD eutrophication project: Nutrient loading-lake response relationships and trophic state indices. EPA 600/3-78-008. U.S. EPA, Corvallis, OR.

Reckhow, K. 1979. Quantitative techniques for the assessment of lake quality. EPA-440/5-79-015. U.S. Environ. Protection Agency, OWPS, Washington, D.C.

Renk, R. R., V. D. Adams, and D. B. Porcella. 1978. Naturally occurring organic compounds in eutrophic Hyrum Reservoir, Utah. Q-78/001. Utah Water Research Laboratory, Utah State University, Logan, - UT.

Rupp, G., and V. D. Adams. 1981. Calcium carbonate precipitation as influenced by stream primary production. Q-81/01. Utah Water Research Laboratory, Utah State University, Logan, UT.

Sawyer, C. N. 1947. Fertilization of lakes by agricultural and urban drainage. New Eng. Water Works Assn. 61:109-122.

Smith, V., and J. Shapiro. 1981. Chlorophyll-phosphorus relations in individual lakes. Their importance to lake restoration strategies. Env. Sci. Technol. 15:444-451.

SPSS Inc. 1983. SPSS-X users guide. McGraw-Hill Book Co., New York, NY.

State of Utah Department of Health. 1984. State of Utah public drinking water regulations, third revision. State of Utah, Department of Health, Division of Environmental Health, Bureau of Public Water Supplies, Salt Lake City, UT.

Symons, J. M., et al. 1971. Committee report: Artificial destratification in reservoirs. Journal AWWA 63(9):597.

UWRL. 1974. Planning for water quality in the Bear River system. PRWG-142-1. Utah Water Research Laboratory, Utah State University, Logan, UT.

UWRL. 1976. Water quality working paper for Bear River Basin cooperative (type IV) study, Idaho, Utah, Wyoming. U.S. Department of Agriculture, Soil Conservation Service, Salt Lake City, UT.

UWRL. 1980. Bear River 208 water quality data summary. Unpublished data. Utah Water Research Laboratory, Utah State University, Logan, UT.

Utah Department of Health. 1978. Wastewater disposal regulations. Part II: Standards of Quality for Waters of the State. State of Utah, Department of Social Services, Division of Health. Salt Lake City, UT. 31 p.

Vollenweider, R. A. 1975. Input-output models with special reference to the phosphorus loading concept in limnology. Schweitz.2. Hydrol. 37:53-83.

Vollenweider, R. A. 1976. Advances in defining critical loading levels for phosphorus in lake eutrophication. Mem. 1st Ital. Idrobio. 33:53-83.

Wieneke, S., D. B. George, D. S. Filip, and B. Finney. 1980. Evaluation of livestock runoff as a source of water pollution in northern Utah. Q-80/02. Utah Water Research Laboratory, Utah State University, Logan, UT.

Williams, J. D. H., H. Shear, and R. L. Thomas. 1980. Availability to Scenedesmus quadricauda of different forms of phosphorus in sedimentary materials for the Great Lakes. Limnol. Oceanog. 25:1-11.

Appendix A

Summary water quality statistics for sampling stations on the Bear River and its tributaries between January 1977 and December 1983. Units of measure for each of the variables are the same as in Table 5.

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490950 BEAR R. AT UTAH-WYO STATE LINE

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	5.868	6.091	0.0	22.500	65
DO	9.296	1.890	5.099	13.190	61
CONDFLD	197.088	119.787	17.000	770.000	57
COND25C	184.348	94.897	4.000	430.000	69
PH	19.386	89.123	.500	704.000	61
TSS	11.553	31.314	0.0	175.000	60
NO2NO3	.682	2.198	.020	11.000	44
TKN	.340	.350	.100	2.500	67
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	6.874	5.853	1.000	26.500	52
COD	16.681	18.106	2.000	120.000	47
NH3NH4	.214	.321	0.0	1.000	65
CA	26.881	14.549	4.000	66.000	67
MNDISS	0.0	0.0	0.0	0.0	5
K	.952	.280	0.0	2.000	63
NA	3.672	6.258	1.000	46.000	67
HCO3	109.623	60.500	14.000	270.000	69
CO3	.304	1.019	0.0	6.000	69
CL2	2.062	3.691	0.0	30.000	65
SO4	11.134	3.494	4.000	21.000	67
TOTP	.096	.317	0.0	2.000	61
TOTALK	89.551	51.021	1.000	221.000	69
TOTHARD	98.060	52.487	18.000	232.000	67
TURB	5.219	12.304	.100	80.000	68
TDS	115.000	55.647	32.000	260.000	70
AS	1.227	1.586	0.0	10.000	55
CD	1.255	1.022	0.0	5.000	55
CU	9.776	4.345	0.0	35.000	58
IRON	.236	.323	0.0	2.250	67
PB	6.582	4.328	0.0	20.000	55
MN	23.220	38.155	0.0	250.000	59
HG	.110	.084	0.0	.600	63
SE	.804	.577	0.0	4.500	56
ZN	15.259	16.071	0.0	83.000	58
TCOLIMF	2.227	1.533	0.0	3.924	17
TCOLIMPN	2.136	.698	1.146	3.380	31
FCOLIMF	.868	1.041	0.0	2.903	26
FCOLIMPN	1.658	.584	0.0	3.176	31
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.146	.259	1.000	2.000	37
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	20.000	.	20.000	20.000	1
F	.071	.088	.010	.580	42
NO3	.355	1.298	0.0	10.000	60
NO2	.030	.021	0.0	.050	52
ORTHOP	.022	.028	0.0	.200	56
SI	6.977	1.849	4.000	13.000	44
CO2	2.841	5.910	0.0	49.000	69

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490890 BEAR R. BELOW WOODRUFF RESERVOIR

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	11.028	6.279	1.299	21.000	52
DO	9.138	2.704	4.699	20.290	51
CONDFLD	425.723	243.474	188.000	1890.000	47
COND25C	473.566	261.548	220.000	2080.000	53
PH	8.193	.402	7.399	9.099	51
TSS	9.865	10.708	0.0	52.000	52
NO2NO3	.165	.230	0.0	.900	25
TKN	.730	.939	.200	7.000	53
OG	8.099	.	8.099	8.099	1
TOC	12.309	9.477	3.000	44.000	42
COD	18.462	7.585	10.000	39.000	26
NH3NH4	.327	.396	0.0	1.000	56
CA	45.041	10.285	20.000	67.000	49
MNDISS	1.250	2.500	0.0	5.000	4
K	2.396	.792	1.000	4.000	48
NA	28.592	63.363	5.000	455.000	49
HCO3	211.560	50.014	120.000	340.000	50
CO3	.860	1.980	0.0	8.000	50
CL2	29.735	51.477	4.000	365.000	49
SO4	27.776	17.948	11.000	125.000	49
TOTP	.076	.053	.010	.300	53
TOTALK	174.824	40.573	98.000	279.000	51
TOTHARD	188.020	44.296	108.000	312.000	49
TURB	9.083	8.819	1.899	44.000	51
TDS	278.857	142.623	142.000	1164.000	56
AS	1.344	.663	.500	3.000	45
CD	1.000	0.0	1.000	1.000	44
CU	10.217	2.097	5.000	20.000	46
IRON	.191	.143	0.0	.810	51
PB	5.227	1.054	5.000	10.000	44
MN	89.578	90.442	10.000	420.000	45
HG	.130	.173	0.0	1.000	50
SE	.778	.420	.500	3.000	45
ZN	19.500	18.152	5.000	85.000	44
TCOLIMF	2.297	1.207	.477	4.606	10
TCOLIMPN	2.329	.918	1.176	3.968	22
FCOLIMF	.605	.547	0.0	1.708	20
FCOLIMPN	1.604	.710	0.0	3.380	20
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.983	.857	1.199	4.000	12
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	512.999	893.943	10.000	2760.000	10
F	.212	.208	.090	.880	13
NO3	.260	.394	0.0	2.149	39
NO2	.021	.020	0.0	.070	36
ORTHOP	.050	.033	0.0	.160	38
SI	8.769	2.833	5.000	15.000	13
CO2	2.373	1.385	1.000	8.000	51

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490610 BEAR RIVER AT UTAH-IDAHO STATE LINE

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	10.627	8.215	0.0	24.000	37
DO	9.275	2.071	5.299	14.190	36
CONDFLD	746.097	189.542	170.000	1200.000	31
COND25C	854.558	293.990	505.000	1970.000	43
PH	8.067	.272	7.599	8.599	34
TSS	50.769	72.826	.500	461.000	39
NO2NO3	.535	.344	.050	1.549	37
TKN	.742	.732	.100	4.199	40
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	9.446	6.887	0.0	31.000	35
COD	16.024	6.206	8.000	32.000	42
NH3NH4	.222	.295	0.0	1.000	45
CA	60.375	11.544	33.000	85.000	40
MNDISS	.714	1.890	0.0	5.000	7
K	9.250	6.755	4.000	43.000	40
NA	61.425	46.596	20.000	310.000	40
HCO3	336.400	49.884	230.000	426.000	40
CO3	2.974	9.480	0.0	54.000	39
CL2	78.077	67.328	23.000	425.000	39
SO4	62.450	15.013	29.000	92.000	40
TOTP	.083	.038	.020	.200	41
TOTALK	278.575	41.031	195.000	349.000	40
TOTHARD	310.000	44.835	200.000	390.000	40
TURB	16.902	10.595	1.899	42.290	40
TDS	491.913	144.686	290.000	1152.000	46
AS	2.727	1.206	1.000	5.500	33
CD	1.000	0.0	1.000	1.000	30
CU	10.000	2.540	5.000	20.000	32
IRON	1.178	4.905	.050	31.000	39
PB	6.133	2.474	5.000	15.000	30
MN	42.485	18.054	20.000	87.000	33
HG	.122	.125	0.0	.600	37
SE	.742	.254	.500	1.000	31
ZN	20.484	20.420	5.000	80.000	31
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.458	.855	0.0	3.633	18
FCOLIMF	0.0	.	0.0	0.0	1
FCOLIMPN	2.135	.806	.845	3.380	18
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	2.435	1.352	1.000	7.000	17
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	350.000	.	350.000	350.000	1
F	.308	.126	.150	.760	22
NO3	.514	.357	0.0	1.549	25
NO2	.055	.056	0.0	.200	20
ORTHOP	.035	.018	.010	.080	23
SI	15.478	3.462	7.000	23.000	23
CO2	3.475	1.502	1.000	7.000	40

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490368 BEAR RIVER BELOW CONF WITH CUB RIVER

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	13.140	7.603	.500	24.090	25
DO	8.844	2.263	5.399	15.000	24
CONDFLD	662.158	153.204	200.000	920.000	19
COND25C	793.808	338.719	495.000	2350.000	26
PH	8.056	.357	7.299	8.599	23
TSS	90.917	59.739	20.000	265.000	24
NO2NO3	.708	.505	.200	2.419	18
TKN	.768	.268	.100	1.500	22
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	9.517	7.461	2.099	33.000	21
COD	16.550	7.000	6.000	32.000	20
NH3NH4	.262	.371	0.0	1.000	26
CA	58.350	6.675	45.000	72.000	20
MNDISS	2.000	2.739	0.0	5.000	5
K	7.409	2.702	4.000	16.000	22
NA	45.136	17.214	19.000	98.000	22
HCO3	324.273	42.040	236.000	410.000	22
CO3	.095	.436	0.0	2.000	21
CL2	53.727	18.739	21.000	107.000	22
SO4	56.455	16.355	23.000	85.000	22
TOTP	.154	.163	.020	.820	21
TOTALK	266.955	34.946	194.000	336.000	22
TOTHARD	293.727	41.433	210.000	372.000	22
TURB	38.832	20.203	11.000	87.000	22
TDS	452.560	89.212	268.000	638.000	25
AS	3.235	.710	2.000	4.000	17
CD	1.000	0.0	1.000	1.000	15
CU	10.000	0.0	10.000	10.000	16
IRON	.809	1.069	.100	5.409	22
PB	5.133	.516	5.000	7.000	15
MN	69.118	36.795	15.000	160.000	17
HG	.135	.208	0.0	1.000	20
SE	.800	1.162	.500	5.000	15
ZN	19.118	14.495	5.000	60.000	17
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.372	.782	1.362	3.380	9
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.903	.821	1.602	3.968	9
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	3.622	1.286	1.599	6.000	9
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.281	.059	.200	.360	7
NO3	.565	.417	.050	1.199	10
NO2	.033	.052	0.0	.100	6
ORTHOP	.071	.045	.020	.170	8
SI	14.571	3.867	8.000	21.000	7
CO2	3.955	1.558	2.000	8.000	22

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490340 BEAR R. BIO CONF W SUMMIT CREEK

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	12.333	7.506	5.000	20.000	3
DO	10.295	1.831	9.000	11.590	2
CONDFLD	830.000	197.990	690.000	970.000	2
COND25C	796.667	151.438	690.000	970.000	3
PH	8.299	0.0	8.299	8.299	2
TSS	130.000	20.000	110.000	150.000	3
NO2NO3	.600	.	.600	.600	1
TKN	1.000	.	1.000	1.000	1
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	1.000	.	1.000	1.000	1
COD	VARIABLE IS MISSING FOR EVERY CASE.				
NH3NH4	.050	.071	0.0	.100	2
CA	58.333	15.503	43.000	74.000	3
MNDISS	2.500	3.536	0.0	5.000	2
K	10.667	5.033	6.000	16.000	3
NA	65.333	24.826	45.000	93.000	3
HCO3	325.333	65.767	276.000	400.000	3
CO3	0.0	0.0	0.0	0.0	3
CL2	88.333	35.346	65.000	129.000	3
SO4	55.333	17.243	40.000	74.000	3
TOTP	.080	.	.080	.080	1
TOTALK	266.667	54.049	226.000	328.000	3
TOTHARD	289.333	61.232	252.000	360.000	3
TURB	51.000	9.539	42.000	61.000	3
TDS	484.667	129.326	410.000	634.000	3
AS	3.000	.	3.000	3.000	1
CD	VARIABLE IS MISSING FOR EVERY CASE.				
CU	5.000	.	5.000	5.000	1
IRON	.783	.464	.400	1.299	3
PB	VARIABLE IS MISSING FOR EVERY CASE.				
MN	110.000	.	110.000	110.000	1
HG	.050	.071	0.0	.100	2
SE	VARIABLE IS MISSING FOR EVERY CASE.				
ZN	25.000	.	25.000	25.000	1
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	1.775	.522	1.362	2.362	3
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	3.105	.238	2.968	3.380	3
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	3.566	1.601	2.000	5.199	3
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.280	.096	.210	.390	3
NO3	.750	.477	.300	1.250	3
NO2	.050	.087	0.0	.150	3
ORTHOP	.027	.012	.020	.040	3
SI	14.667	6.506	8.000	21.000	3
CO2	2.333	.577	2.000	3.000	3

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490326 BEAR R. AB CUTLER RES AT BRIDGE 1 MI W OF BENSON

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	12.550	8.103	1.000	23.890	14
DO	7.959	2.355	5.299	12.090	13
CONDFLD	684.714	117.110	462.000	909.000	14
COND25C	678.571	101.592	470.000	885.000	14
PH	8.030	.322	7.399	8.500	13
TSS	68.357	41.418	5.000	133.000	14
NO2NO3	.595	.289	.200	1.250	14
TKN	.714	.192	.400	1.000	14
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	9.810	5.695	2.099	18.890	14
COD	13.929	4.047	10.000	22.000	14
NH3NH4	.429	.443	.100	1.000	14
CA	56.000	16.155	5.000	72.000	13
MNDISS	VARIABLE IS MISSING FOR EVERY CASE.				
K	6.000	2.219	1.000	11.000	14
NA	39.786	18.339	3.000	82.000	14
HCO3	309.571	35.294	230.000	336.000	14
CO3	0.0	0.0	0.0	0.0	13
CL2	50.286	22.228	23.000	116.000	14
SO4	50.429	14.805	25.000	66.000	14
TOTP	.846	2.635	.040	10.000	14
TOTALK	253.786	28.842	189.000	276.000	14
TOTHARD	280.714	35.549	200.000	316.000	14
TURB	47.046	33.335	10.390	155.000	14
TDS	433.571	102.960	264.000	690.000	14
AS	3.107	1.196	1.000	6.000	14
CD	1.000	0.0	1.000	1.000	14
CU	12.500	9.354	10.000	45.000	14
IRON	.572	.225	.230	.920	14
PB	6.000	2.418	5.000	13.000	14
MN	63.571	26.049	10.000	115.000	14
HG	.107	.027	.100	.200	14
SE	.500	0.0	.500	.500	14
ZN	20.000	23.939	5.000	85.000	14
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	VARIABLE IS MISSING FOR EVERY CASE.				
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	3912.000	.	3912.000	3912.000	1
F	VARIABLE IS MISSING FOR EVERY CASE.				
NO3	VARIABLE IS MISSING FOR EVERY CASE.				
NO2	VARIABLE IS MISSING FOR EVERY CASE.				
ORTHOP	VARIABLE IS MISSING FOR EVERY CASE.				
SI	VARIABLE IS MISSING FOR EVERY CASE.				
CO2	4.357	1.008	3.000	7.000	14

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490198 BEAR RIVER BELOW CUTLER RESERVOIR

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	11.406	8.710	0.0	26.000	36
DO	9.863	3.163	5.199	17.790	34
CONDFLD	775.000	406.430	125.000	2118.000	29
COND25C	924.357	426.838	450.000	2140.000	42
PH	8.249	.558	7.399	10.500	34
TSS	52.195	48.316	.500	175.000	39
NO2NO3	.527	.303	.100	1.149	35
TKN	.863	.951	.200	5.000	41
OG	13.690	.	13.690	13.690	1
TOC	10.247	8.993	1.000	38.790	34
COD	20.053	13.575	4.000	85.000	38
NH3NH4	.221	.296	0.0	1.000	43
CA	60.333	9.511	42.000	81.000	36
MNDISS	0.0	0.0	0.0	0.0	6
K	8.486	4.127	1.000	18.000	37
NA	94.027	90.651	18.000	360.000	37
HCO3	304.703	41.572	196.000	384.000	37
CO3	3.500	9.602	0.0	54.000	36
CL2	135.944	140.786	22.000	530.000	36
SO4	50.703	15.156	21.000	75.000	37
TOTP	.117	.047	.050	.200	40
TOTALK	253.595	32.797	179.000	315.000	37
TOTHARD	290.649	39.888	194.000	360.000	37
TURB	28.603	25.236	1.899	100.000	36
TDS	541.644	241.444	252.000	1272.000	45
AS	3.274	1.527	1.500	7.000	31
CD	1.000	0.0	1.000	1.000	29
CU	10.500	2.403	5.000	15.000	30
IRON	.518	.419	.080	1.919	37
PB	5.828	1.872	3.000	10.000	29
MN	54.161	29.389	10.000	130.000	31
HG	.151	.229	0.0	1.299	35
SE	.733	.254	.500	1.000	30
ZN	22.000	21.063	5.000	110.000	31
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.448	1.138	1.362	5.380	17
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.316	1.069	.602	4.362	17
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	3.950	3.690	1.199	17.000	18
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.292	.127	.030	.600	18
NO3	.533	.380	0.0	1.449	20
NO2	.068	.097	0.0	.400	17
ORTHOP	.056	.027	.020	.100	18
SI	13.278	2.782	7.000	17.000	18
CO2	3.297	1.746	1.000	8.000	37

SUMMARY STATISTICS 1/77 - 12/83
STATION: 490379 CUB R. W OF FRANKLIN IDAHO

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	8.826	7.258	0.0	23.190	28
DO	8.605	2.375	2.899	12.000	28
CONDFLD	399.750	158.446	32.000	765.000	28
COND25C	460.357	167.221	160.000	820.000	28
PH	7.976	.499	6.500	8.699	26
TSS	38.875	53.256	2.000	194.000	24
NO2NO3	.757	.603	.150	3.149	30
TKN	.793	.585	.100	2.399	29
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	8.302	7.537	1.000	29.790	25
COD	16.370	7.821	8.000	42.000	27
NH3NH4	.817	1.146	.100	5.000	30
CA	54.269	10.114	36.000	81.000	26
MNDISS	VARIABLE IS MISSING FOR EVERY CASE.				
K	4.107	2.923	1.000	10.000	28
NA	23.357	22.158	2.000	72.000	28
HCO3	244.500	56.965	157.000	376.000	28
CO3	1.963	3.907	0.0	12.000	27
CL2	23.679	28.745	1.000	86.000	28
SO4	17.321	14.029	6.000	85.000	28
TOTP	.243	.450	.020	2.500	30
TOTALK	203.500	47.277	134.000	308.000	28
TOTHARD	203.857	49.260	140.000	358.000	28
TURB	17.318	20.737	1.500	76.790	27
TDS	269.500	101.886	148.000	594.000	30
AS	2.648	1.839	.500	8.000	27
CD	1.037	.192	1.000	2.000	27
CU	9.815	1.688	5.000	15.000	27
IRON	2.287	6.709	.110	26.000	27
PB	5.741	1.810	5.000	10.000	27
MN	55.214	29.506	20.000	125.000	28
HG	.170	.196	.100	1.000	27
SE	.870	.861	.500	5.000	27
ZN	19.964	21.322	5.000	80.000	28
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.780	.843	1.362	3.633	5
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	1.876	.471	1.362	2.362	4
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	3.500	2.517	1.000	7.000	4
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	43.257	27.176	22.790	74.090	3
F	.247	.143	.060	.570	11
NO3	1.190	.831	.200	3.149	11
NO2	.080	.095	.050	.350	10
ORTHOP	.169	.188	.020	.600	11
SI	16.455	6.314	6.000	27.000	11
CO2	3.893	3.735	1.000	16.000	28

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490425 CUB R. ABOVE W DAIRYMANS COOP OUTFALL

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	8.067	6.554	.500	22.500	12
DO	10.475	2.936	6.000	15.390	10
CONDFLD	470.556	101.040	300.000	625.000	9
COND25C	558.571	130.773	280.000	845.000	14
PH	7.860	.375	7.000	8.299	10
TSS	32.613	22.944	1.000	68.000	15
NO2NO3	1.084	.654	.090	2.000	13
TKN	.946	.335	.500	1.699	15
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	8.699	10.221	1.000	29.000	10
COD	19.154	10.534	8.000	46.000	13
NH3NH4	.187	.200	0.0	.800	15
CA	56.000	6.849	46.000	69.000	12
MNDISS	0.0	0.0	0.0	0.0	2
K	5.917	2.151	2.000	10.000	12
NA	34.917	22.749	4.000	92.000	12
HCO3	278.000	42.212	168.000	336.000	12
CO3	3.667	4.812	0.0	12.000	12
CL2	35.083	29.883	3.000	117.000	12
SO4	14.279	5.660	.350	21.000	12
TOTP	.238	.195	.050	.800	14
TOTALK	233.917	36.079	141.000	276.000	12
TOTHARD	228.167	31.960	150.000	260.000	12
TURB	21.825	9.583	8.899	37.000	12
TDS	312.278	68.319	168.000	472.000	18
AS	3.400	1.506	1.000	5.000	10
CD	1.000	0.0	1.000	1.000	8
CU	8.750	2.315	5.000	10.000	8
IRON	.566	.327	.150	1.279	12
PB	7.500	2.673	5.000	10.000	8
MN	64.200	29.169	25.000	105.000	10
HG	.200	.200	0.0	.600	10
SE	1.000	0.0	1.000	1.000	8
ZN	17.900	10.246	5.000	40.000	10
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.959	.655	1.362	3.633	12
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.711	1.094	1.362	4.968	12
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	3.126	.961	2.199	5.299	11
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.219	.080	.060	.350	12
NO3	1.336	.592	.250	2.000	13
NO2	.062	.057	0.0	.200	12
ORTHOP	.168	.107	.040	.370	12
SI	14.000	3.464	6.000	18.000	12
CO2	1.917	1.240	1.000	5.000	12

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490370 CUB RIVER ABOVE CONF W BEAR RIVER

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	8.454	6.412	.500	22.500	18
DO	9.578	2.741	3.299	16.190	17
CONDFLD	448.154	108.084	300.000	618.000	13
COND25C	490.778	137.782	300.000	880.000	18
PH	8.082	.298	7.500	8.500	17
TSS	68.889	49.945	20.000	218.000	18
NO2NO3	1.147	.678	.250	2.199	14
TKN	.842	.403	.300	1.599	19
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	10.947	12.323	1.000	42.000	16
COD	15.176	7.333	8.000	37.000	17
NH3NH4	.437	.523	0.0	2.000	19
CA	53.600	7.908	36.000	68.000	15
MNDISS	1.667	2.887	0.0	5.000	3
K	4.063	2.462	1.000	8.000	16
NA	18.500	11.027	3.000	40.000	16
HCO3	262.063	49.749	182.000	332.000	16
CO3	1.800	5.427	0.0	21.000	15
CL2	21.267	16.628	2.000	63.000	15
SO4	16.125	5.476	8.000	28.000	16
TOTP	.216	.163	.050	.750	17
TOTALK	215.375	41.331	149.000	272.000	16
TOTHARD	217.750	39.710	150.000	280.000	16
TURB	30.629	19.268	6.000	66.290	16
TDS	278.412	67.468	162.000	388.000	17
AS	3.408	1.681	.800	8.000	13
CD	1.000	0.0	1.000	1.000	13
CU	10.385	1.387	10.000	15.000	13
IRON	.611	.339	.230	1.500	16
PB	5.231	.832	5.000	8.000	13
MN	73.462	32.621	35.000	140.000	13
HG	.156	.228	0.0	1.000	16
SE	.692	.253	.500	1.000	13
ZN	22.308	18.553	5.000	75.000	13
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	3.031	.845	1.602	3.968	6
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.195	.526	1.362	2.633	6
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	3.833	2.100	2.000	7.500	6
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	1164.000	.	1164.000	1164.000	1
F	.195	.126	.070	.360	4
NO3	1.000	.592	.250	1.699	7
NO2	.062	.095	0.0	.200	4
ORTHOP	.158	.122	.040	.340	6
SI	12.500	4.203	8.000	17.000	4
CO2	3.563	2.097	2.000	10.000	16

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490350 SUMMIT CREEK ABOVE CONF W BEAR R.

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	8.778	5.540	3.000	18.000	9
DO	11.206	1.878	8.299	14.190	9
CONDFLD	406.667	49.329	350.000	440.000	3
COND25C	494.500	102.265	350.000	650.000	10
PH	8.144	.361	7.599	8.699	9
TSS	32.500	25.304	5.000	95.000	10
NO2NO3	.875	.742	.350	1.399	2
TKN	.675	.436	.100	1.299	8
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	6.000	5.967	0.0	17.000	6
COD	16.600	9.581	4.000	30.000	5
NH3NH4	.067	.071	0.0	.200	9
CA	56.125	11.395	37.000	72.000	8
MNDISS	1.429	2.440	0.0	5.000	7
K	3.625	2.200	1.000	7.000	8
NA	11.500	6.279	3.000	20.000	8
HCO3	310.250	64.520	234.000	392.000	8
CO3	1.000	2.828	0.0	8.000	8
CL2	9.286	5.090	4.000	19.000	7
SO4	15.500	4.781	10.000	22.000	8
TOTP	.077	.056	.010	.180	7
TOTALK	254.250	52.874	192.000	321.000	8
TOTHARD	246.500	42.180	196.000	320.000	8
TURB	11.625	9.939	5.000	35.000	8
TDS	272.400	61.252	208.000	410.000	10
AS	2.000	.	2.000	2.000	1
CD	5.000	.	5.000	5.000	1
CU	5.000	.	5.000	5.000	1
IRON	.431	.641	.050	2.000	8
PB	VARIABLE IS MISSING FOR EVERY CASE.				
MN	30.000	.	30.000	30.000	1
HG	.029	.049	0.0	.100	7
SE	VARIABLE IS MISSING FOR EVERY CASE.				
ZN	10.000	.	10.000	10.000	1
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	3.005	.587	1.954	3.633	10
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.859	.705	1.954	3.968	10
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.990	.640	1.000	2.799	10
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.129	.047	.060	.200	8
NO3	1.394	.757	.400	2.250	9
NO2	.038	.052	0.0	.150	8
ORTHOP	.027	.017	0.0	.050	9
SI	11.500	4.276	6.000	18.000	8
CO2	2.625	.518	2.000	3.000	8

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490570 LITTLE BEAR R-BL CNFL-S FK LITTLE BEAR RIVER

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	9.981	5.223	2.000	19.000	32
DO	9.393	2.288	1.899	13.390	31
CONDFLD	360.720	92.492	30.000	457.000	25
COND25C	385.690	53.747	250.000	450.000	29
PH	8.266	.384	7.399	9.099	30
TSS	19.404	29.952	1.399	127.000	28
NO2NO3	.259	.366	.050	1.919	24
TKN	.497	.521	.100	2.399	29
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	5.320	6.271	0.0	24.000	24
COD	14.083	12.951	4.000	73.000	24
NH3NH4	.263	.368	0.0	1.000	30
CA	51.231	7.095	29.000	61.000	26
MNDISS	0.0	0.0	0.0	0.0	6
K	1.346	.689	1.000	4.000	26
NA	7.538	2.319	4.000	13.000	26
HCO3	242.577	29.329	169.000	278.000	26
CO3	.640	2.289	0.0	10.000	25
CL2	8.385	2.639	4.000	16.000	26
SO4	14.269	3.639	8.000	24.000	26
TOTP	.061	.074	0.0	.350	28
TOTALK	201.192	22.668	148.000	230.000	26
TOTHARD	207.923	23.141	150.000	236.000	26
TURB	6.372	9.557	1.000	50.290	26
TDS	222.750	30.147	116.000	256.000	32
AS	1.425	1.350	.500	6.000	20
CD	1.000	0.0	1.000	1.000	18
CU	10.100	3.110	5.000	20.000	20
IRON	.148	.101	0.0	.400	25
PB	5.000	0.0	5.000	5.000	18
MN	16.350	10.444	5.000	50.000	20
HG	.137	.251	0.0	1.299	24
SE	.579	.187	.500	1.000	19
ZN	15.600	16.233	5.000	75.000	20
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.519	.759	1.362	3.968	15
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.450	.772	1.362	3.968	15
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.814	.723	1.000	3.299	14
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.101	.024	.070	.140	10
NO3	.295	.140	0.0	.450	11
NO2	.028	.036	0.0	.100	9
ORTHOP	.018	.016	0.0	.050	9
SI	10.100	.568	9.000	11.000	10
CO2	2.462	.859	1.000	5.000	26

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490565 LITTLE BEAR RIVER BELOW HYRUM RES

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	10.058	7.009	1.000	21.000	12
DO	11.311	2.244	7.699	14.090	12
CONDFLD	396.667	140.380	200.000	590.000	6
COND25C	522.500	100.704	300.000	720.000	14
PH	7.557	1.569	2.699	8.299	12
TSS	6.408	5.079	0.0	15.000	12
NO2NO3	.393	.169	.150	.650	7
TKN	.508	.171	.200	.800	13
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	8.357	14.085	1.000	40.000	7
COD	11.900	4.630	6.000	19.000	10
NH3NH4	.093	.073	0.0	.300	14
CA	61.889	6.173	53.000	72.000	9
MNDISS	1.667	4.082	0.0	10.000	6
K	3.889	1.537	1.000	6.000	9
NA	12.222	2.279	9.000	16.000	9
HCO3	310.889	26.965	270.000	348.000	9
CO3	1.333	4.000	0.0	12.000	9
CL2	12.556	1.878	10.000	15.000	9
SO4	16.667	2.000	14.000	20.000	9
TOTP	.071	.026	.040	.140	13
TOTALK	257.000	23.890	221.000	285.000	9
TOTHARD	259.556	21.208	236.000	292.000	9
TURB	2.433	1.161	1.399	4.000	9
TDS	286.667	51.450	196.000	362.000	18
AS	4.333	2.082	2.000	6.000	3
CD	1.000	0.0	1.000	1.000	2
CU	7.500	3.536	5.000	10.000	2
IRON	.116	.096	0.0	.330	9
PB	5.000	0.0	5.000	5.000	2
MN	23.333	15.275	10.000	40.000	3
HG	.025	.046	0.0	.100	8
SE	1.000	0.0	1.000	1.000	3
ZN	17.500	3.536	15.000	20.000	2
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	2.898	1.007	1.362	4.176	15
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.384	.724	1.362	3.633	15
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	2.345	.609	1.599	3.699	11
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.203	.053	.090	.260	9
NO3	.625	.394	.100	1.399	12
NO2	.061	.129	0.0	.400	9
ORTHOP	.048	.052	.010	.170	8
SI	19.333	6.519	12.000	29.000	9
CO2	3.444	2.297	1.000	9.000	9

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490500 LITTLE BEAR R. ABOVE CONF W LOGAN R.

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	10.599	6.819	.200	22.500	37
DO	8.977	1.969	4.799	13.590	36
CONDFLD	501.367	116.190	91.000	673.000	30
COND25C	544.333	88.278	330.000	700.000	42
PH	7.993	.330	7.099	8.599	35
TSS	32.461	21.100	.700	70.000	39
NO2NO3	1.066	.573	.100	2.759	35
TKN	.714	.551	.100	3.299	41
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	9.758	11.217	0.0	42.000	32
COD	14.886	6.614	6.000	34.000	35
NH3NH4	.415	.998	0.0	6.099	41
CA	64.083	10.322	37.000	78.000	36
MNDISS	5.286	10.275	0.0	27.000	7
K	4.649	1.736	2.000	8.000	37
NA	19.378	5.698	7.000	32.000	37
HCO3	297.351	44.192	186.000	380.000	37
CO3	2.306	5.455	0.0	23.000	36
CL2	26.861	8.043	8.000	39.000	36
SO4	17.462	7.306	.100	45.000	37
TOTP	.142	.166	.040	.900	40
TOTALK	246.514	35.984	159.000	312.000	37
TOTHARD	261.351	38.644	170.000	350.000	37
TURB	13.895	7.451	2.299	32.000	37
TDS	318.222	53.360	204.000	422.000	45
AS	3.387	1.424	1.000	7.000	31
CD	1.000	0.0	1.000	1.000	29
CU	9.828	1.627	5.000	15.000	29
IRON	.362	.293	.070	1.409	37
PB	7.241	8.408	5.000	50.000	29
MN	37.161	14.731	15.000	70.000	31
HG	.114	.114	0.0	.600	35
SE	.750	.254	.500	1.000	30
ZN	18.172	19.894	5.000	95.000	29
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	3.391	.900	1.954	5.380	16
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.575	.953	1.362	4.633	17
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	2.093	.556	1.299	3.299	16
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	136.556	85.804	31.390	234.000	5
F	.207	.065	.100	.380	18
NO3	1.066	.416	.250	2.409	21
NO2	.061	.049	0.0	.200	18
ORTHOP	.052	.046	0.0	.200	18
SI	17.444	3.729	10.000	23.000	18
CO2	3.703	2.655	1.000	15.000	37

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490520 LOGAN R. AT MOUTH OF CONYON

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	6.984	3.445	.700	15.500	41
DO	10.048	1.662	6.899	13.790	40
CONDFLD	327.471	79.409	48.000	441.000	34
COND25C	341.459	47.708	270.000	555.000	37
PH	8.361	.538	6.500	9.399	39
TSS	5.794	7.463	0.0	40.000	36
NO2NO3	.179	.050	.090	.250	31
TKN	.219	.154	0.0	.700	37
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	4.056	6.031	0.0	29.000	30
COD	11.250	3.910	4.000	20.000	32
NH3NH4	.208	.325	0.0	1.000	36
CA	45.912	6.603	30.000	61.000	34
MNDISS	1.429	3.780	0.0	10.000	7
K	1.030	.305	0.0	2.000	33
NA	3.314	1.491	1.000	9.000	35
HCO3	216.057	23.512	170.000	268.000	35
CO3	1.371	2.510	0.0	10.000	35
CL2	3.371	1.750	1.000	9.000	35
SO4	11.801	3.890	.050	18.000	35
TOTP	.043	.041	0.0	.200	36
TOTALK	178.857	17.742	144.000	202.000	35
TOTHARD	186.086	19.135	140.000	220.000	35
TURB	2.294	3.026	.200	16.390	35
TDS	192.756	18.550	158.000	238.000	41
AS	.904	.530	.500	2.000	26
CD	1.000	0.0	1.000	1.000	26
CU	13.462	18.749	5.000	105.000	26
IRON	.071	.044	0.0	.200	35
PB	5.769	1.840	5.000	10.000	26
MN	9.808	1.721	5.000	15.000	26
HG	.155	.279	0.0	1.599	33
SE	.712	.252	.500	1.000	26
ZN	21.407	22.626	5.000	95.000	27
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	1.753	.590	1.362	2.968	17
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	1.673	.678	0.0	2.633	13
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.292	.360	1.000	2.099	14
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	VARIABLE IS MISSING FOR EVERY CASE.				
F	.072	.023	.030	.120	19
NO3	.178	.077	0.0	.250	20
NO2	.035	.023	0.0	.050	17
ORTHOP	.022	.016	0.0	.080	21
SI	5.895	.658	5.000	7.000	19
CO2	2.229	1.087	1.000	5.000	35

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490504 LOGAN R. AB CNFL W/LITTLE BEAR R. AT CR 376 XING

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	8.792	4.807	0.0	20.190	25
DO	9.309	1.731	6.899	13.090	25
CONDFLD	364.400	76.483	170.000	511.000	25
COND25C	388.074	49.600	310.000	495.000	27
PH	8.164	.504	7.000	9.099	23
TSS	16.542	17.490	3.000	63.000	24
NO2NO3	.553	.797	.150	4.699	30
TKN	.386	.459	.100	2.599	29
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	4.847	5.003	1.000	23.190	27
COD	12.643	3.477	5.000	20.000	28
NH3NH4	.370	.419	.100	1.000	30
CA	50.846	8.098	30.000	61.000	26
MNDISS	VARIABLE IS MISSING FOR EVERY CASE.				
K	1.179	.548	1.000	3.000	28
NA	4.821	1.588	2.000	9.000	28
HCO3	235.429	33.717	176.000	306.000	28
CO3	.786	1.988	0.0	8.000	28
CL2	5.536	2.411	1.000	11.000	28
SO4	16.357	4.840	9.000	28.000	28
TOTP	.060	.069	.010	.400	30
TOTALK	194.321	27.479	144.000	251.000	28
TOTHARD	208.964	26.260	164.000	260.000	28
TURB	5.003	3.618	.500	15.000	27
TDS	222.448	33.531	160.000	294.000	29
AS	1.054	.906	.500	5.000	28
CD	1.000	0.0	1.000	1.000	28
CU	10.714	4.017	5.000	30.000	28
IRON	.145	.080	.030	.420	28
PB	5.821	1.827	5.000	10.000	28
MN	12.571	5.160	10.000	35.000	28
HG	.136	.119	.100	.600	28
SE	.911	.839	.500	5.000	28
ZN	17.214	14.891	5.000	55.000	28
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	3.340	.275	2.968	3.633	4
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	1.862	.577	1.362	2.362	4
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.500	.577	1.000	2.000	4
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	399.300	191.950	196.600	578.300	3
F	.091	.017	.060	.120	10
NO3	.435	.214	.150	.850	10
NO2	.062	.049	.020	.200	10
ORTHOP	.022	.004	.020	.030	10
SI	7.200	.919	6.000	9.000	10
CO2	2.286	.763	1.000	3.000	28

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490540 BLACKSMITH FK ABOVE CONF LOGAN RIVER

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	10.353	5.623	.100	21.000	29
DO	9.528	1.638	6.399	12.390	28
CONDFLD	426.818	103.693	80.000	605.000	22
COND25C	463.935	97.726	330.000	740.000	31
PH	8.014	.297	7.399	8.500	27
TSS	11.800	13.902	.300	71.000	28
NO2NO3	.585	.518	.050	2.649	25
TKN	.335	.178	.100	.800	31
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	7.590	10.135	.100	38.500	23
COD	12.929	7.353	2.000	42.000	28
NH3NH4	.540	1.469	0.0	8.099	30
CA	57.630	10.627	35.000	83.000	27
MNDISS	0.0	0.0	0.0	0.0	6
K	1.444	.698	1.000	3.000	27
NA	6.222	1.625	4.000	10.000	27
HCO3	259.222	72.816	3.000	370.000	27
CO3	1.385	3.086	0.0	10.000	26
CL2	7.185	1.902	5.000	11.000	27
SO4	23.915	7.194	.700	32.000	27
TOTP	.115	.288	.010	1.599	29
TOTALK	220.481	44.437	131.000	303.000	27
TOTHARD	242.111	42.438	172.000	332.000	27
TURB	4.981	6.795	.800	33.290	27
TDS	256.235	48.226	184.000	362.000	34
AS	1.190	.968	.500	5.000	21
CD	1.000	0.0	1.000	1.000	19
CU	9.474	1.577	5.000	10.000	19
IRON	.149	.089	0.0	.460	27
PB	7.211	3.750	5.000	19.000	19
MN	11.714	4.724	5.000	23.000	21
HG	.136	.170	0.0	.600	25
SE	.789	.254	.500	1.000	19
ZN	27.900	22.238	5.000	80.000	20
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	3.240	.751	2.176	4.380	17
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	2.980	.637	1.362	3.968	17
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	1.539	.559	1.000	2.799	15
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	1200.000	.	1200.000	1200.000	1
F	.132	.056	.070	.330	18
NO3	.716	.582	.100	2.399	20
NO2	.041	.026	0.0	.100	17
ORTHOP	.021	.015	0.0	.060	18
SI	9.222	2.340	7.000	14.000	18
CO2	2.667	1.271	1.000	5.000	27

SUMMARY STATISTICS 1/77 - 12/83

STATION: 490319 NEWTON CREEK ABOVE NEWTON RESERVOR

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM	VALID N
TEMP	10.636	5.630	4.000	20.000	13
DO	9.934	1.968	7.299	13.890	13
CONDFLD	606.429	77.980	480.000	745.000	7
COND25C	580.769	84.381	440.000	730.000	13
PH	8.299	.249	7.899	8.699	11
TSS	150.549	260.252	5.000	1020.000	16
NO2NO3	1.482	.321	.950	2.049	9
TKN	.633	.498	0.0	1.699	15
OG	VARIABLE IS MISSING FOR EVERY CASE.				
TOC	6.500	7.106	0.0	20.000	9
COD	21.273	26.822	2.000	95.000	11
NH3NH4	.138	.236	0.0	.900	13
CA	69.300	11.176	51.000	90.000	10
MNDISS	1.200	2.683	0.0	6.000	5
K	5.900	1.792	3.000	9.000	10
NA	20.900	5.507	13.000	28.000	10
HCO3	282.000	32.455	204.000	322.000	10
CO3	5.300	10.584	0.0	33.000	10
CL2	40.222	7.463	24.000	50.000	9
SO4	31.800	9.295	19.000	50.000	10
TOTP	.151	.059	.060	.280	14
TOTALK	234.500	28.602	167.000	280.000	10
TOTHARD	273.000	36.335	192.000	324.000	10
TURB	56.090	86.368	6.899	290.000	10
TDS	353.438	72.259	182.000	472.000	16
AS	6.200	1.304	4.000	7.000	5
CD	1.000	0.0	1.000	1.000	3
CU	9.200	4.550	5.000	16.000	5
IRON	4.999	12.344	.250	40.000	10
PB	7.000	2.646	5.000	10.000	3
MN	102.800	90.278	10.000	243.000	5
HG	.037	.052	0.0	.100	8
SE	.900	.224	.500	1.000	5
ZN	31.200	32.283	5.000	81.000	5
TCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
TCOLIMPN	3.266	.674	2.362	4.633	14
FCOLIMF	VARIABLE IS MISSING FOR EVERY CASE.				
FCOLIMPN	3.226	.644	1.602	3.968	14
FSTREPMF	VARIABLE IS MISSING FOR EVERY CASE.				
BOD5	2.637	2.986	1.000	12.090	13
FLOWMGD	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWGPM	VARIABLE IS MISSING FOR EVERY CASE.				
FLOWCFS	6.000	.	6.000	6.000	1
F	.295	.055	.180	.350	10
NO3	1.558	.507	.800	2.599	11
NO2	.256	.655	0.0	2.000	9
ORTHOP	.112	.104	.020	.400	11
SI	33.000	6.325	22.000	43.000	10
CO2	2.500	1.716	1.000	7.000	10

Appendix B

Water quality analysis results of selected field and laboratory chemical analyses of samples taken from the Bear River and its tributaries between May 1984 and May 1985. Both annual average and monthly data are tabulated.

Average for 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	13.4 7.5-17.5 (3)	8.0 8.0 (1)	9.0 7.9-9.6 (3)	16.2 5.0-25.0 (5)	<26 <3-50 (5)	750 750 (1)	- - (0)	- - (0)	- - (0)	15.6 5.9-27.0 (4)	22 20-24 (4)	2 1-3 (5)	0.5 0.2-0.6 (4)	3.48 2.60-7.0 (3)
Bear R. bl. Oneida res. [490620]	9.7 1.5-18.0 (5)	9.3 7.4-12.2 (3)	9.7 8.1-10.8 (4)	18.9 2.5-53.2 (7)	28 10-44 (7)	705 608-730 (2)	394 334-454 (2)	281 272-290 (2)	297.5 265-330 (2)	19.6 2.8-39.2 (4)	20 10-28 (4)	2 1-3 (7)	0.6 0.2-1.0 (5)	9.43 5.91-23.50 (5)
Bear R. W. Fairview, ID [490610]	8.3 0.0-20.4 (11)	8.2 6.8-9.0 (10)	9.3 7.2-12.2 (10)	46.7 11.4-200.0 (12)	90 22-332 (12)	794 486-1120 (11)	452 322-648 (12)	270 212-317 (12)	298.1 228-340 (12)	12.2 2.9-31.3 (12)	<16 <10-32 (12)	2 1-4 (9)	0.6 0.3-0.9 (12)	9.90 0.5-18.11 (6)
Bear R. W. Richmond [490382]	8.6 (-0.1)-22.2 (11)	8.2 6.8-9.0 (10)	9.0 6.5-11.4 (9)	46.1 6.1-198.0 (12)	65 15-151 (12)	720 495-935 (11)	440 348-522 (12)	269 298-310 (12)	304.1 284-356 (12)	12.5 5.7-33.7 (10)	<21 <10-34 (11)	3 2-5 (9)	0.6 0.2-0.8 (12)	9.27 5.0-14.0 (6)
Bear R. bl. confl. w/Cub R. [490368]	9.6 0.0-22.8 (9)	8.2 7.2-9.2 (8)	9.2 6.7-12.9 (7)	37.5 7.2-127.7 (11)	57 17-114 (11)	695 452-916 (9)	424 302-498 (11)	263 198-307 (11)	292.4 212-348 (11)	12.4 1.9-23.1 (10)	<16 <10-29 (10)	3 2-4 (8)	0.6 0.3-0.8 (11)	11.67 2.91-20.0 (3)
Bear R. ab. Cutler res. [490326]	9.1 (-0.2)-22.5 (11)	8.2 7.1-9.1 (11)	9.4 6.3-11.7 (10)	38.1 125.5-6.3 (12)	55 11-108 (12)	743 445-1160 (11)	426 294-504 (12)	266 200-308 (12)	296.3 208-356 (12)	12.5 3.9-40.4 (12)	<18 <10-32 (12)	3 1-5 (9)	0.6 0.3-1.1 (12)	6.39 0.0-11.15 (6)
Bear R. bl. Cutler res. [490198]	10.4 0.1-22.7 (11)	8.3 8.0-8.6 (11)	8.7 5.9-11.9 (11)	45.2 6.4-159.0 (11)	56 9-108 (11)	703 423-1223 (11)	404 258-490 (11)	251 192-300 (11)	281.1 200-336 (11)	22.5 2.3-104.2 (10)	<18 <10-35 (10)	3 2-4 (9)	0.7 0.2-1.2 (11)	9.78 0.64-15.50 (6)
Bear R. near Honeyville [490170]	12.9 3.1-22.0 (9)	8.1 7.2-8.5 (9)	7.7 5.8-9.3 (9)	58.9 11.0-210.0 (8)	<65 <3-162 (9)	655 423-869 (9)	- - (0)	254 254 (1)	- - (0)	14.7 5.2-24.9 (7)	<19 <10-34 (7)	3 2-4 (9)	0.8 0.6-1.7 (9)	11.25 5.0-18.98 (6)

Average for 1984

Station	NH4-N (mg/l)	NO2-N (mg/l)	NO3-N (mg/l)	TP (mg/l)	PO4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO4 (mg/l)	T. Fe (mg/l)	T. Mn (μg/l)
Bear R. ab. Oneida res. [490630]	<0.1 <0.1 (4)	<0.01 <0.01 (4)	0.50 0.18-0.91 (4)	0.07 0.06-0.10 (4)	0.03 0.01-0.05 (4)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	0.30 0.24-0.39 (5)	43 10-65 (5)
Bear R. bl. Oneida res. [490620]	<0.09 0.06-<0.1 (5)	<0.01 <0.01-.01 (5)	0.49 .02-.85 (5)	<0.08 <.01-0.12 (5)	<0.02 <.01-0.06 (5)	36 29-42 (2)	6 5-6 (2)	60 50-69 (2)	36 34-38 (2)	36 26-46 (2)	61 45-77 (2)	0.23 0.06-0.39 (7)	<36.4 <10-70 (7)
Bear R. W. Fairview, ID [490610]	<0.15 <0.1-0.5 (12)	<0.01 <0.01 (8)	0.63 0.35-1.05 (8)	0.18 .03-0.63 (12)	<0.04 <.01-0.11 (8)	52 23-126 (12)	8 4-17 (12)	60 56-64 (12)	36 21-44 (12)	61 24-151 (12)	57 31-73 (12)	0.56 0.21-1.36 (12)	<69.2 <10-135 (12)
Bear R. W. Richmond [490382]	<0.13 0.07-0.5 (12)	<0.02 <.01-0.05 (9)	0.66 .39-1.23 (9)	0.10 .04-0.26 (12)	<0.02 <.01-0.08 (9)	45 24-62 (12)	6 4-8 (12)	59 50-67 (12)	38 19-49 (12)	50 28-66 (12)	60 33-76 (12)	0.51 0.20-1.18 (12)	55 15-90 (12)
Bear R. bl. confl. w/Cub R. [490368]	<0.14 <0.1-0.4 (11)	<0.02 <.01-.05 (8)	0.72 .39-1.4 (8)	0.10 .05-.19 (11)	<0.03 <.01-.13 (8)	43 20-54 (11)	6 4-7 (11)	59 50-67 (11)	36 20-47 (11)	47 23-60 (11)	56 26-70 (11)	0.42 .12-1.08 (11)	40.9 15-70 (11)
Bear R. ab. Cutler res. [490326]	<0.13 <0.1-0.4 (12)	<0.02 <.01-0.1 (8)	0.66 .42-1.13 (8)	0.10 .02-0.22 (12)	<0.02 <.01-0.03 (7)	45 20-60 (12)	6 4-8 (12)	58 46-66 (12)	37 22-47 (12)	49 24-62 (12)	55 25-70 (12)	0.45 0.08-1.06 (12)	46.7 15-85 (12)
Bear R. bl. Cutler res. [490198]	<0.15 <0.1-0.4 (11)	<0.04 <.01-.14 (9)	0.69 .35-1.46 (9)	0.11 .03-0.21 (10)	<0.03 <.01-0.05 (8)	39 16-59 (11)	5 3-9 (11)	58 51-64 (11)	33 18-43 (11)	43 18-60 (11)	46 21-64 (11)	<0.48 <.03-0.94 (11)	45 10-100 (11)
Bear R. near Honeyville [490170]	<0.48 <0.1-0.4 (9)	<0.01 <.01-.01 (7)	0.57 .32-.93 (7)	0.65 .14-.34 (9)	<0.07 <.01-.24 (8)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	0.54 0.05-1.04 (8)	61.9 20-100 (8)

Average for 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
W. Side Canal [490195]	14.1 1.4-22.9 (7)	8.3 8.0-8.7 (7)	7.6 6.1-9.8 (7)	29.4 0-58 (8)	56 0-118 (8)	630 417-856 (7)	- - (0)	- - (0)	- - (0)	11.6 0-21.6 (8)	<13 0-34 (8)	3 0-6 (8)	0.7 0.0-1.6 (8)	7.48 1.77-15.41 (5)
Cub R. W. Franklin, ID [490379]	8.7 0.0-18.2 (10)	8.4 7.4-9.1 (10)	9.8 7.5-11.9 (9)	19.9 2.5-61.1 (10)	<49 <3-147 (11)	396 267-650 (10)	241 178-412 (11)	187 159-205 (11)	180.7 152-196 (11)	8.4 1-29.2 (11)	<15 <10-34 (11)	2 1-4 (9)	0.4 0.1-1.0 (11)	17.85 0.64-41.50 (5)
Cub R. W. Richmond [490425]	11.3 2.1-17.6 (7)	8.3 8.0-8.9 (7)	8.7 7.0-10.9 (6)	36.8 10-61 (8)	85 19-133 (8)	438 282-660 (7)	- - (0)	- - (0)	- - (0)	11.1 2.8-26.3 (8)	<18 <10-27 (8)	3 1-5 (9)	0.7 0.4-1.1 (8)	20.55 6.0-56.0 (5)
Logan R. ab. confl. w/L Bear R. [490504]	7.0 2.0-12.2 (10)	8.5 8.1-9.1 (9)	9.3 6.3-11.1 (10)	8.3 2.5-22.0 (11)	<15 <3-49 (11)	436 310-680 (10)	231 200-254 (11)	207 172-220 (11)	215.9 176-232 (11)	7.5 1.4-14.5 (10)	<13 <10-29 (10)	<2 <1-3 (9)	<0.3 <0.1-0.7 (11)	1.38 0.0-4.0 (5)
L. Bear R. W. Avon [490570]	8.3 2.3-15.9 (11)	8.4 7.7-9.1 (10)	8.9 5.8-11.3 (11)	14.5 1.8-74.0 (12)	<32 <3-182 (10)	427 297-706 (11)	232 204-258 (12)	205 203-221 (12)	209.5 168-232 (12)	9.3 3.0-24.1 (9)	<14 <10-28 (10)	<2 <1-3 (9)	0.4 0.1-0.8 (10)	9.03 0.0-37.0 (6)
L. Bear bl. Hyrum res. [490565]	12.1 4.5-20.4 (8)	8.3 7.9-8.7 (8)	8.9 4.7-10.9 (8)	5.2 1-15 (9)	<8 <3-24 (9)	437 309-745 (8)	- - (0)	- - (0)	- - (0)	7.4 2.7-19.1 (8)	<15 <10-28 (8)	2 1-3 (9)	<0.3 <0.1-0.5 (9)	4.39 0.0-16.36 (6)
L. Bear ab. confl. w/Logan R. [490500]	8.3 1.5-16.0 (11)	8.0 7.4-8.7 (10)	7.8 5.3-11.0 (10)	22.5 4.4-113.0 (12)	35 1-76 (12)	606 472-878 (11)	346 260-416 (12)	263 233-290 (12)	290.3 244-332 (12)	10.4 3.0-24.6 (11)	<15 <10-29 (11)	4 1-7 (9)	1.1 0.1-2.2 (12)	20.74 11.0-42.01 (6)

Average for 1984

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
W. Side Canal [490195]	<0.13 0-0.4 (8)	<0.01 0-<0.01 (8)	0.46 0-0.75 (8)	0.11 0-0.19 (8)	<0.03 0-0.03 (8)	0 - (1)	0 - (1)	0 - (1)	0 - (1)	0 - (1)	0 - (1)	0.48 0-1.06 (8)	53.6 15-80 (7)
Cub R. W. Franklin, ID [490379]	<0.1 <0.01-0.20 (11)	<0.02 <0.01-.06 (9)	0.84 .42-1.96 (9)	0.11 .06-.19 (11)	<0.04 <.01-0.13 (8)	13 3-32 (11)	3 1-7 (11)	49 43-53 (11)	14 11-17 (11)	9 1-32 (11)	15 5-66 (11)	0.40 0.05-1.4 (11)	34.1 <10-70 (11)
Cub R. W. Richmond [490425]	<0.1 <0.1-0.1 (8)	<0.01 <0.01-0.03	1.16 .39-1.65 (8)	0.19 .11-.35 (8)	0.10 .03-0.3 (8)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	0.57 0.19-1.06 (8)	66.8 15-115 (8)
Logan R. ab. confl. w/L Bear R. [490504]	<0.1 0.05-0.10 (11)	<0.01 <0.01 (9)	0.36 .28-.42 (9)	<0.04 <.01-.07 (11)	<0.01 <.01-0.03 (9)	5 1-7 (11)	1 1 (11)	55 48-61 (11)	19 14-23 (11)	4 1-9 (11)	14 7-17 (11)	0.16 0.06-0.42 (11)	<13.2 <10-25 (11)
L. Bear R. W. Avon [490570]	<0.1 <0.05-0.10 (12)	<0.01 <0.01 (9)	0.29 0.20-0.42 (9)	0.07 .01-.25 (12)	<0.02 <.01-.04 (9)	8 4-12 (12)	1 1-2 (12)	52 45-56 (12)	19 10-24 (12)	9 5-13 (12)	11 8-13 (12)	<0.22 <.03-1.05 (12)	<25.4 <10-115 (12)
L. Bear bl. Hyrum res. [490565]	<0.11 <0.10-0.20 (11)	<0.01 <0.01 (9)	0.73 0.20-1.27 (9)	0.18 .01-.29 (9)	<0.01 <.01-.02 (9)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	- - (0)	0.13 0.03-0.49 (9)	<13.3 <10-30 (9)
L. Bear ab. confl. w/Logan R. [490500]	<0.5 <0.05-1.50 (12)	<0.26 <0.01-2 (9)	1.61 0.65-2.24 (9)	0.25 .04-.57 (12)	<0.21 <.01-.54 (9)	19 13-34 (12)	4 1-6 (12)	66 61-70 (12)	30 22-38 (12)	21 8-44 (12)	30 13-44 (12)	0.26 0.05-0.60 (12)	<25.4 <10-50 (12)

Sample Date: 1 May 1984

Station	Temp. (C)	pH	D.O. (mg/l)	Turb. (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard. as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	7.5	-	9.6	25.0	50	-	-	-	-	5.9	24	2	0.6	4.0
Bear R. bl. Oneida res. [490620]	6.5	-	10.8	28.0	28	-	-	-	-	2.8	28	2	0.6	6.0
Bear R. W. Fairview, ID [490610]														4.0
Bear R. W. Richmond [490382]														5.0
Bear R. bl. confl. w/Cub R. [490368]	10.0	8.2	8.6	58	98	632	392	239	269	4.5	26	2	0.8	-
Bear R. ab. Cutler res. [490326]	10.5	8.1	8.3	48	68	627	390	239	271	5.6	21	2	0.7	5.0
Bear R. bl Cutler res. [4901981]	9.2	8.2	10.6	45	77	577	374	228	255	6.3	<10	3	0.6	6.0
Bear R. near Honeyville [490170]	9.0	8.2	8.3	45	69	578	-	-	-	5.2	34	4	0.6	5.0
W. Side Canal [490195]														
Cub R. W. Franklin, ID [490379]	9.8	8.3	8.6	15	46	324	204	171	170	2.0	24	3	0.5	-
Cub R. W. Richmond [490425]	8.8	8.1	8.4	61.0	119	383	-	-	-	2.8	24	4	0.9	56.0
Logan R. ab. confl. w/L. Bear R. [4905041]	8.6	8.4	11.1	14.0	23	364	220	203	203.0	2.0	<10	3	0.5	2.0
L. Bear R. W. Avon [490570]	8.1	8.3	8.7	74.0	182	297	238	187	174.0	4.5	22	3	0.8	37.0
L. Bear bl. Hyrum res. [490565]	8.4	8.3	9.9	10.0	7	345	-	-	-	2.9	15	2	0.4	11.0
L. Bear ab. confl. w/Logan R. [490500]	10.7	7.9	7.7	5.0	28	642	386	250	332.0	4.5	<10	7	1.6	38.0

1 May 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	<0.10	<0.01	0.91	0.10	0.01	-	-	-	-	-	-	0.39	45.0
Bear R. bl. Oneida res. [490620]	<0.10	<0.01	0.85	0.08	0.02	-	-	-	-	-	-	0.34	35.0
Bear R. W. Fairview, ID [490610]													
Bear R. W. Richmond [490382]													
Bear R. bl. confl. w/Cub R. [490368]	0.10	0.02	1.15	0.15	0.02	41	6	58	30	44	52	1.08	70.0
Bear R. ab. Cutler res. [490326]	0.100	0.02	1.13	0.14	0.03	41	6	59	30	46	51	1.06	65.0
Bear R. bl. Cutler res. [490198]	0.10	0.02	0.91	0.13	0.03	37	5	56	28	42	41	0.87	55.0
Bear R. near Honeyville [490170]	0.10	0.01	0.93	0.140	<0.01	-	-	-	-	-	-	0.85	55.0
W. Side Canal [490195]													
Cub R. W. Franklin, ID [490379]	<0.01	0.01	1.21	0.08	0.03	8	2	48	12	5	10	0.56	25.0
Cub R. W. Richmond [490425]	0.10	0.02	1.65	0.20	0.07	-	-	-	-	-	-	0.97	85.0
Logan R. ab. confl. w/L. Bear R. [490504]	<0.10	<0.01	0.30	0.06	<0.01	6	1	53	17	6	12	0.31	10.0
L. Bear R. W. Avon [490570]	<0.10	<0.01	0.23	0.25	0.03	12	2	53	10	13	12	1.05	115.0
L. Bear bl. Hyrum res. [490565]	0.10	<0.01	0.65	0.20	0.01	-	-	-	-	-	-	0.21	15.0
L. Bear ab. confl. w/Logan R. [490500]	0.70	0.06	1.91	0.32	0.28	24	6	70	38	28	40	0.27	25.0

30 May 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	15.3	-	9.6	13.	13.	-	-	-	-	27.	20.	3.	0.5	7.0
Bear R. bl. Oneida res. [490620]	16.2	-	9.8	12.	40.	-	-	-	-	39.2	10.	3.	0.7	8.0
Bear R. W. Fairview, ID [490610]	15.5	8.1	8.2	27.	50.	515.	322.	212.	228.	15.2	17.	4.	0.4	6.0
Bear R. W. Richmond [490382]	17.4	8.1	7.9	27.	49.	525.	348.	210.	228.	33.7	34.	4.	0.7	7.0
Bear R. bl. confl. w/Cub R. [490368]	18.2	8.1	7.5	42.	70.	470.	302.	198.	212.	20.6	<10.	2.	0.7	-
Bear R. ab. Cutler res. [490326]	18.5	8.0	7.1	60.	100.	475.	294.	200.	208.	21.2	29.	4.	0.9	13.0
Bear R. bl. Cutler res. [490198]	17.1	8.1	7.7	55.	108.	445.	258.	192.	200.	16.4	30.	2.	0.8	11.0
Bear R. near Honeyville [490170]	17.7	7.9	6.7	31.	39.	-	-	-	-	22.3	32.	2.	0.6	6.0
W. Side Canal [490195]	17.1	8.0	6.6	58.	118.	-	-	-	-	11.7	34.	2.	0.7	11.0
Cub R. W. Franklin, ID [490379]	11.1	8.3	8.4	50.	147.	290.	178.	159.	152.	29.2	18.	2.	0.5	13.0
Cub R. W. Richmond [490425]	12.9	8.2	7.5	56.	133.	-	-	-	-	17.0	27.	2.	0.7	14.0
Logan R. ab. confl. w/L Bear R. [490504]	9.2	8.5	8.7	22.	49.	330.	218.	172.	176.	14.5	17.	3.	0.7	4.0
L. Bear R. W. Avon [490570]	11.4	8.4	7.8	20.	66.	320.	212.	164.	168.	24.1	<10.	2.	0.4	16.0
L. Bear bl. Hyrum res. [490565]	13.3	8.3	8.5	15.	24.	-	-	-	-	19.1	<10.	2.	0.3	5.0
L. Bear ab. confl. w/Logan R. [490500]	13.5	7.8	6.3	28.	64.	550.	372.	244.	272.	24.6	17.	5.	1.0	11.0

30 May 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (μg/l)
Bear R. ab. Oneida res. [490630]	<0.1	<0.01	0.18	0.06	0.01	-	-	-	-	-	-	0.29	55.
Bear R. bl. Oneida res. [490620]	<0.1	<0.01	0.02	0.09	0.01	-	-	-	-	-	-	0.20	70.
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.35	0.10	0.01	23.	4.	56.	21.	24.	31.	0.37	80.
Bear R. W. Richmond [490382]	<0.1	<0.01	0.39	0.05	0.01	24.	4.	59.	19.	28.	33.	0.53	60.
Bear R. bl. confl. w/Cub R. [490368]	<0.1	0.01	0.41	0.11	0.02	20.	4.	51.	20.	23.	26.	0.68	70.
Bear R. ab. Cutler res. [490326]	<0.1	<0.01	0.47	0.15	0.02	20.	4.	46.	22.	24.	25.	0.90	80.
Bear R. bl. Cutler res. [490198]	0.1	<0.01	0.47	0.03	0.03	16.	3.	51.	18.	18.	21.	0.89	65.
Bear R. near Honeyville [490170]	<0.1	<0.01	0.32	0.17	0.03	-	-	-	-	-	-	0.50	70.
W. Side Canal [490195]	0.1	<0.01	0.46	0.15	0.03	-	-	-	-	-	-	1.06	75.
Cub R. W. Franklin, ID [490379]	0.1	<0.01	0.59	0.12	<0.01	3.	1.	43.	11.	1.	5.	1.40	70.
Cub R. W. Richmond [490425]	0.1	<0.01	0.39	0.14	0.03	-	-	-	-	-	-	1.06	74.
Logan R. ab. confl. w/L Bear R. [490504]	0.1	<0.01	0.32	0.06	<0.01	4.	1.	48.	14.	1.0	7.	0.42	25.
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.28	0.07	0.01	5.	1.	45.	14.	5.	8.	0.53	35.
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.20	0.17	<0.01	-	-	-	-	-	-	0.49	30.
L. Bear ab. confl. w/Logan R. [490500]	0.3	<0.01	1.55	0.17	0.11	13.	4.	61.	29.	13.	37.	0.49	30.

10 July 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as CaCO3 (mg/l)	TOC (mg/l)	COD (mg/l)	BOD5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	5.0	<3.	-	-	-	-	14.8	21.	1.	0.2	1.8
Bear R. bl. Oneida res. [490620]	-	-	-	20.	44.	-	-	-	-	30.3	24.	2.	0.3	14.0
Bear R. W. Fairview, ID [490610]	20.4	8.2	7.2	25.	65.	565.	340.	231.	248.	23.9	32.	2.	0.4	7.9
Bear R. W. Richmond [490382]	22.2	8.2	6.5	36.	86.	630.	374.	241.	260.	17.4	41.	5.	0.5	6.9
Bear R. bl. confl. w/Cub R. [490368]	22.8	8.2	6.7	53.	96.	620.	350.	238.	256.	16.8	25.	3.	0.5	7.9
Bear R. ab. Cutler res. [490326]	22.5	8.2	6.3	58.	108.	655.	370.	236.	256.	17.6	32.	3.	0.8	3.8
Bear R. bl. Cutler res. [490198]	20.5	8.2	5.9	48.	92.	580.	396.	228.	240.	17.6	35.	3.	0.7	7.9
Bear R. near Honeyville [490170]	21.1	8.1	5.8	62.	162.	-	-	-	-	24.9	<10.	3.	1.7	4.5
W. Side Canal [490195]	20.6	8.2	6.1	48.	90.	-	-	-	-	19.9	<10.	3.	1.6	2.9
Cub R. W. Franklin, ID [490379]	18.2	8.5	7.5	4.0	16.	360.	192.	180.	172.	15.6	34.	2.	0.1	4.8
Cub R. W. Richmond [490425]	17.6	8.1	7.0	38.	104.	-	-	-	-	19.5	23.	1.	0.4	7.9
Logan R. ab. confl. w/L Bear R. [490504]	12.0	8.5	8.8	5.0	17.	380.	200.	189.	196.	11.2	29.	2.	<0.1	0
L. Bear R. W. Avon [490570]	15.9	8.4	7.5	9.9	29.	430.	245.	221.	224.	9.9	28.	1.	0.1	0
L. Bear bl. Hyrum res. [490565]	20.4	7.9	8.0	1.0	<3.	-	-	-	-	12.4	28.	1.	0.2	0
L. Bear ab. confl. w/Logan R. [490500]	16.0	8.0	7.4	18.	63.	560.	340.	262.	288.	19.4	29.	4.	0.7	15.0

10 July 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	<0.1	<0.01	0.36	0.07	0.03	-	-	-	-	-	-	0.27	10.
Bear R. bl. Oneida res. [490620]	<0.1	<0.01	0.43	0.12	0.06	-	-	-	-	-	-	0.35	35.
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.43	0.27	0.11	30.	5.	58.	25.	31.	32.	0.21	<10.
Bear R. W. Richmond [490382]	<0.1	<0.01	0.40	0.12	0.08	33.	5.	59.	27.	34.	38.	0.29	15.
Bear R. bl. confl. w/Cub R. [490368]	<0.1	<0.01	0.39	0.17	0.13	32.	5.	61.	25.	34.	36.	0.16	20.
Bear R. ab. Cutler res. [490326]	<0.1	<0.01	0.42	0.18	-	37.	5.	54.	29.	46.	35.	0.19	30.
Bear R. bl. Cutler res. [490198]	<0.1	0.14	0.37	-	-	30.	4.	58.	23.	33.	27.	0.59	50.
Bear R. near Honeyville [490170]	0.1	<0.01	0.46	0.34	0.24	-	-	-	-	-	-	0.99	100.
W. Side Canal [490195]	0.1	<0.01	0.39	0.15	0.12	-	-	-	-	-	-	0.65	55.
Cub R. W. Franklin, ID [490379]	<0.1	<0.01	0.42	0.07	0.04	7.	2.	51.	11.	4.	8.	0.05	<10.
Cub R. W. Richmond [490425]	<0.1	<0.01	0.62	0.16	0.13	-	-	-	-	-	-	0.20	15.
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.28	0.05	<0.03	3.	1.	50.	18.	1.	10.	0.10	<10.
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.39	0.07	0.04	8.	2.	56.	20.	9.	11.	0.12	10.
L. Bear bl. Hyrum res. [490565]	0.2	<0.01	1.27	0.16	0.02	-	-	-	-	-	-	0.09	<10.
L. Bear ab. confl. w/Logan R. [490500]	<0.01	0.22	1.13	0.22	0.20	13.	4.	62.	32.	8.	36.	0.35	20.

07 Aug. 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	15.0	32	-	-	-	-	14.7	23	1	0.5	-
Bear R. bl. Oneida res. [490620]	-	-	-	6.5	10	-	-	-	-	6.1	17	1	0.2	23.5
Bear R. W. Fairview, ID [490610]	-	-	-	40.0	78	-	462	266	292	31.3	28	2	0.4	0.5
Bear R. W. Richmond [490382]	-	-	-	30.0	76	-	400	259	280	6.0	15	3	0.8	14.0
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	35.0	114	-	405	256	280	2.2	17	4	0.6	20.0
Bear R. ab. Cutler res. [490326]	-	-	-	38.0	79	-	422	257	284	6.1	19	5	0.7	8.5
Bear R. bl. Cutler res. [490198]	22.7	8.0	6.5	48.0	90	636	372	246	264	22.8	27	4	0.8	15.5
Bear R. near Honeyville [490170]	22.0	7.2	6.5	55.0	98	631	-	-	-	8.1	<10	3	0.6	9.5
W. Side Canal [490195]	22.9	8.3	7.0	40.0	69	615	-	-	-	9.7	<10	3	1.1	3.5
Cub R. W. Franklin, ID [490379]	-	-	-	3.5	<3	-	282	205	192	9.5	<10	3	1.0	41.5
Cub R. W. Richmond [490425]	-	-	-	35.0	79	-	-	-	-	6.8	<10	4	0.8	6.0
Logan R. ab. confl. w/L Bear R. [490504]	-	-	-	6.5	17	-	232	220	220	3.7	<10	1	0.1	0
L. Bear R. W. Avon [490570]	-	-	-	2.8	<3	-	246	220	232	7.7	<10	1	0.4	0
L. Bear bl. Hyrum res. [490565]	-	-	-	1.0	<3	-	-	-	-	5.3	<10	1	0.1	0
L. Bear ab. confl. w/Logan R. [490500]	-	-	-	30.0	76	-	332	253	272	7.4	17	3	0.7	35.0

07 Aug. 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	<0.1	<0.01	0.55	0.06	0.05	-	-	-	-	-	-	0.24	65
Bear R. bl. Oneida res. [490620]	<0.1	<0.01	0.49	<0.01	<0.01	-	-	-	-	-	-	0.10	25
Bear R. W. Fairview, ID [490610]	0.1	<0.01	0.50	0.11	<0.01	53	9	64	32	66	47	0.65	60
Bear R. W. Richmond [490382]	0.1	<0.01	0.49	0.04	<0.01	42	6	62	30	40	50	0.76	75
Bear R. bl. confl. w/Cub R. [490368]	<0.1	<0.01	0.45	0.08	<0.01	43	6	61	31	44	48	0.94	65
Bear R. ab. Cutler res. [490326]	<0.1	<0.01	0.49	0.11	<0.01	47	7	66	29	50	47	0.93	80
Bear R. bl. Cutler res. [490198]	<0.1	<0.01	0.35	0.10	<0.01	36	5	59	28	36	38	0.94	100
Bear R. near Honeyville [490170]	<0.1	<0.01	0.36	0.18	<0.01	-	-	-	-	-	-	1.04	100
W. Side Canal [490195]	0.1	<0.01	0.35	0.19	<0.01	-	-	-	-	-	-	0.72	80
Cub R. W. Franklin, ID [490379]	0.2	<0.01	0.97	0.18	0.13	31	6	50	17	32	12	0.07	30
Cub R. W. Richmond [490425]	0.1	<0.01	1.37	0.12	0.07	-	-	-	-	-	-	0.56	95
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.39	<0.01	<0.01	5	1	54	20	2	14	0.22	10
L. Bear R. W. Avon [490570]	0.1	<0.01	0.31	0.03	0.03	8	1	54	23	7	10	0.14	10
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.77	0.01	<0.01	-	-	-	-	-	-	0.04	<10
L. Bear ab. confl. w/Logan R. [490500]	0.3	<0.01	1.50	0.20	0.15	14	5	62	28	12	29	0.60	50

05 Sep. 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	17.5	8.0	7.9	23.0	31	750	-	-	-	-	-	2	-	2.60
Bear R. bl. Oneida res. [490620]	18.0	8.4	8.1	10.0	10	730	-	-	-	-	-	2	-	5.91
Bear R. W. Fairview, ID [490610]	18.8	8.3	-	28.0	92	790	484	269	380	11.3	14	3	0.9	12.90
Bear R. W. Richmond [490382]	18.4	8.4	-	23.0	41	690	420	261	380	6.8	14	2	0.2	10.80
Bear R. bl. confl. w/Cub R. [490368]	19.6	8.5	-	26.0	56	691	418	257	300	16.4	<10	3	0.6	15.85
Bear R. ab. Cutler res. [490326]	19.0	8.4	-	33.0	64	686	424	277	300	8.5	<10	4	0.3	0
Bear R. bl. Cutler res. [490198]	19.1	8.4	7.0	42.0	94	648	410	253	292	104.2	<10	4	1.2	15.41
Bear R. near Honeyville [490170]	18.8	8.4	6.8	35.0	80	676	-	-	-	8.8	14	3	0.6	17.10
W. Side Canal [490195]	19.2	8.4	6.1	38.0	85	630	-	-	-	8.7	<10	4	0.7	15.41
Cub R. W. Franklin, ID [490379]	16.2	8.5	-	9.0	39	380	236	197	188	5.2	14	4	0.4	15.85
Cub R. W. Richmond [490425]	17.6	8.4	-	48.0	114	424	-	-	-	4.4	13	4	0.5	27.70
Logan R. ab. confl. w/L Bear R. [490504]	12.2	8.5	6.3	5.0	15	410	234	213	232	11.3	<10	1	0.4	0
L. Bear R. W. Avon [490570]	15.2	8.6	5.8	2.5	12	413	234	216	232	8.8	<10	2	0.7	0
L. Bear bl. Hyrum res. [490565]	20.2	8.4	4.7	2.5	16	428	-	-	-	7.7	<10.	2	0.5	0
L. Bear ab. confl. w/Logan R. [490500]	14.2	8.1	5.3	17.0	48	553	336	254	284	3.8	<10.	5	1.7	20.87

05 Sep. 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	0.32	40
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	0.20	30
Bear R. W. Fairview, ID [490610]	0.2	<0.01	0.53	0.19	0.01	64	9	59	39	72	61	0.49	90
Bear R. W. Richmond [490382]	<0.1	<0.01	0.55	0.15	0.01	42	6	54	42	44	61	0.42	75
Bear R. bl. confl. w/Cub R. [490368]	0.1	<0.01	0.51	0.19	0.02	42	6	54	40	43	58	0.17	55
Bear R. ab. Cutler res. [490326]	<0.1	<0.01	0.51	0.02	0.01	43	6	54	40	46	56	0.51	60
Bear R. bl. Cutler res. [490198]	0.2	<0.01	0.53	0.18	0.02	39	5	61	34	42	49	0.63	70
Bear R. near Honeyville [490170]	<0.1	<0.01	0.50	0.27	0.02	-	-	-	-	-	-	0.54	85
W. Side Canal [490195]	<0.1	<0.01	0.45	0.17	0.02	-	-	-	-	-	-	0.59	75
Cub R. W. Franklin, ID [490379]	0.1	<0.01	0.59	0.16	0.06	13	3	50	16	11	9	0.31	55
Cub R. W. Richmond [490425]	0.1	<0.01	1.00	0.30	0.08	-	-	-	-	-	-	0.92	115
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.42	0.07	<0.01	1	1	56	22	2	15	0.19	10
L. Bear R. W. Avon [490570]	0.1	<0.01	0.30	0.13	<0.01	4	1	53	24	7	11	0.12	<10
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.78	0.23	<0.01	-	-	-	-	-	-	0.08	<10
L. Bear ab. confl. w/Logan R. [490500]	0.4	<0.01	1.98	0.33	0.18	16	1	66	29	20	30	0.32	20

02 Oct. 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	13.6	8.0	8.6	18.0	22	735	408	271	300	10.3	<10	2	0.3	-
Bear R. W. Richmond [490382]	12.3	8.1	8.8	18.0	32	672	410	261	312	10.3	11	2	0.4	-
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	13.4	8.3	9.8	20.0	34	684	412	264	308	5.1	15	3	0.6	-
Bear R. bl. Cutler res. [490198]	12.4	8.1	8.4	25.0	38	635	384	254	292	7.7	11	2	0.3	-
Bear R. near Honeyville [490170]	12.2	8.1	8.4	22.0	36	630	-	-	-	15.7	<10	2	0.6	-
W. Side Canal [490195]	12.6	8.2	8.6	26.0	37	621	-	-	-	5.1	<10	2	0.5	-
Cub R. W. Franklin, ID [490379]	14.3	8.2	10.5	7.0	14	342	198	190	192	2.9	<10	1	0.2	-
Cub R. W. Richmond [490425]	13.4	8.0	8.7	34.0	71	420	-	-	-	3.2	<10	3	0.5	-
Logan R. ab. confl. w/L Bear R. [490504]	9.6	8.1	8.6	3.0	3	399	226	215	232	6.3	<10	3	0.1	-
L. Bear R. W. Avon [490570]	12.8	8.2	8.5	1.8	<3	392	216	210	220	7.5	<10	2	0.4	-
L. Bear bl. Hyrum res. [490565]	14.8	8.0	9.6	1.5	<3	433	-	-	-	5.4	<10	2	0.1	-
L. Bear ab. confl. w/Logan R. [490500]	11.3	7.8	7.0	11.0	20	559	260	271	300	3.1	<10	3	1.0	-

02 Oct. 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.1	<0.01	0.61	0.10	<0.01	51	7	56	39	56	62	0.26	65
Bear R. W. Richmond [490382]	<0.1	0.05	0.41	0.08	<0.01	41	6	50	46	41	65	0.35	70
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	<0.1	0.10	0.83	0.08	<0.01	45	7	51	44	50	61	0.28	40
Bear R. bl. Cutler res. [490198]	<0.1	<0.01	0.74	0.12	0.02	37	5	54	38	42	48	0.36	45
Bear R. near Honeyville [490170]	<0.1	<0.01	0.75	0.19	0.02	-	-	-	-	-	-	0.05	35
W. Side Canal [490195]	<0.1	<0.01	0.63	0.07	0.02	-	-	-	-	-	-	0.37	45
Cub R. W. Franklin, ID [490379]	<0.1	0.05	0.52	0.08	<0.01	9	2	50	17	6	9	0.28	50
Cub R. W. Richmond [490425]	<0.1	<0.01	1.29	0.17	0.06	-	-	-	-	-	-	0.42	85
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.40	0.02	0.02	5	1	58	21	4	16	0.10	20
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.25	0.02	<0.01	7	1	48	24	7	12	0.09	20
L. Bear bl. Hyrum res. [490565]	<0.1	<0.01	0.79		<0.01	-	-	-	-	-	-	0.05	10
L. Bear ab. confl. w/Logan R. [490500]	0.4	<0.01	2.24	0.25	0.18	17	4	69	31	18	34	0.20	35

23 Oct. 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	6.1	8.0	8.5	12.0	23	700	448	271	308	13.0	11	2	0.6	18.11
Bear R. W. Richmond [490382]	5.6	7.9	8.6	16.0	35	680	420	266	308	11.0	19	2	0.6	12.02
Bear R. bl. confl. w/Cub R. [490368]	6.0	8.0	9.1	15.0	17	676	417	266	308	23.1	<10	2	0.5	-
Bear R. ab. Cutler res. [490326]	6.0	8.1	9.0	15.0	26	686	418	267	308	13.4	<10	2	0.5	11.15
Bear R. bl. Cutler res. [490198]	4.9	8.2	8.6	15.0	23	635	398	257	292	13.1	10	2	0.5	13.75
Bear R. near Honeyville [490170]	4.8	8.2	8.2	-	<3	645	-	254	-	-	-	2	-	18.98
W. Side Canal [490195]	5.1	8.2	8.9	15.0	24	627	-	-	-	21.6	13	2	0.5	10.29
Cub R. W. Franklin, ID [490379]	5.7	8.2	9.6	3.0	3	354	230	195	196	15.2	<10	2	0.2	11.15
Cub R. W. Richmond [490425]	6.5	8.1	9.4	10.0	19	441	-	-	-	26.3	<10	2	0.6	17.24
Logan R. ab. confl. w/L Bear R. [490504]	4.5	8.1	9.7	2.5	<3	390	230	218	228	8.6	<10	2	0.2	-
L. Bear R. W. Avon [490570]	7.3	8.1	8.6	2.4	8	392	204	215	216	11.1	<10	2	0.1	10.29
L. Bear bl. Hyrum res. [490565]	9.4	8.0	9.2	6.0	<3	429	-	-	-	2.7	15	3	0.4	16.36
L. Bear ab. confl. w/Logan R. [490500]	6.4	7.8	7.8	8.3	8	594	366	274	312	11.1	<10	2	0.9	42.01

23 Oct. 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (μg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.2	<0.01	0.57	0.09	0.01	47	7	59	39	52	59	0.27	15
Bear R. W. Richmond [490382]	0.1	<0.01	0.61	0.07	<0.01	42	6	58	40	44	59	0.34	40
Bear R. bl. confl. w/Cub R. [490368]	0.1	<0.01	0.69	0.07	<0.01	43	7	54	42	45	59	0.09	25
Bear R. ab. Cutler res. [490326]	0.1	<0.01	0.72	0.08	<0.01	42	6	59	39	48	58	0.08	35
Bear R. bl. Cutler res. [490198]	0.1	<0.01	0.68	0.10	0.02	38	6	53	39	42	49	<0.03	20
Bear R. near Honeyville [490170]	3.1	-	-	0.11	-	-	-	-	-	-	-	-	-
W. Side Canal [490195]	0.1	<0.01	0.75	0.10	<0.01	-	-	-	-	-	-	0.31	30
Cub R. W. Franklin, ID [490379]	0.1	<0.01	0.55	0.06	0.04	11	2	53	16	5	8	0.13	10
Cub R. W. Richmond [490425]	0.1	<0.01	1.38	0.11	0.05	-	-	-	-	-	-	0.22	25
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.34	0.05	<0.01	5	1	56	21	6	15	0.07	10
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.20	0.02	<0.01	6	1	50	22	7	11	0.07	10
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.77	0.25	<0.01	-	-	-	-	-	-	0.11	<10
L. Bear ab. confl. w/Logan R. [490500]	0.6	<0.01	2.24	0.24	0.21	23	5	69	34	26	35	0.11	<10

27 Nov. 1984

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as CaCO3 (mg/l)	TOC (mg/l)	COD (mg/l)	BOD5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	1.5	12.2	-	2.5	20	-	334	272	265	-	-	1	-	8.61
Bear R. W. Fairview, ID [490610]	1.4	8.6	9.2	25.0	34	1093	648	317	315	15.8	12	1	0.8	9.76
Bear R. W. Richmond [490382]	1.6	8.7	9.3	28.0	100	805	476	298	325	12.3	<10	2	0.7	7.47
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	12.0	24	-	422	276	293	21.9	<10	2	0.7	2.91
Bear R. ab. Cutler res. [490326]	1.6	8.8	9.9	12.0	24	689	424	274	298	40.4	17	1	0.5	0.64
Bear R. bl. Cutler res. [490198]	1.5	8.6	9.2	11.0	9	660	384	259	317	23.9	17	2	0.8	0.64
Bear R. near Honeyville [490170]	3,1	8.5	9.3	11.0	23	710	-	-	-	18.1	23	2	0.8	10.90
W. Side Canal [490195]	1.4	8.7	9.8	10.0	25	645	-	-	-	15.7	18	6	0.7	1.77
Cub R. W. Franklin, ID [490379]	1.7	9.1	11.2	2.5	7	346	412	195	181	3.1	13	1	0.1	0.64
Cub R. W. Richmond [490425]	2.1	8.9	10.9	12.0	37	457	-	-	-	8.6	25	5	1.1	-
Logan R. ab. confl. w/L Bear R. [490504]	2.8	8.7	9.1	2.5	10	386	230	213	222	6.9	<10	1	0.3	0.64
L. Bear R. W. Avon [490570]	3.3	9.0	10.0	5.0	19	414	258	221	226	11.3	<10	2	0.1	2.91
L. Bear bl. Hyrum res. [490565]	4.5	8.7	10.2	4.0	9	424	-	-	-	3.4	20.	1	<0.1	1.77
L. Bear ab. confl. w/Logan R. [490500]	4.6	8.2	7.3	7.5	19	679	416	284	323	19.2	20.	6	1.8	-

27 Nov. 1984 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	29	5	50	34	26	45	0.06	<10
Bear R. W. Fairview, ID [490610]	0.5	<0.01	1.05	0.12	0.10	126	17	60	40	151	61	0.35	100
Bear R. W. Richmond [490382]	0.5	<0.01	0.89	0.12	0.02	62	8	56	45	66	72	0.36	90
Bear R. bl. confl. w/Cub R. [490368]	0.4	<0.01	0.76	0.09	0.03	46	6	50	41	51	64	0.18	15
Bear R. ab. Cutler res. [490326]	0.4	<0.01	0.67	0.07	0.02	45	6	52	41	49	64	0.17	25
Bear R. bl. Cutler res. [490198]	0.4	<0.01	0.66	0.08	0.03	40	6	61	40	46	54	0.07	10
Bear R. near Honeyville [490170]	0.4	<0.01	0.66	0.20	0.04	-	-	-	-	-	-	0.12	20
W. Side Canal [490195]	0.4	<0.01	0.68	0.08	0.03	-	-	-	-	-	-	0.14	15
Cub R. W. Franklin, ID [490379]	0.1	<0.01	0.75	0.08	0.03	32	7	48	15	6	66	0.07	<10
Cub R. W. Richmond [490425]	0.1	0.01	1.56	0.35	0.30	-	-	-	-	-	-	0.19	40
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.34	0.05	<0.01	6	1	56	20	5	16	0.06	<10
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.24	0.04	0.02	10	2	56	21	13	13	0.12	20
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.64	0.29	<0.01	-	-	-	-	-	-	0.05	15
L. Bear ab. confl. w/Logan R. [490500]	1.5	2.00	0.65	0.57	0.54	34	6	70	36	44	39	0.05	20

02 Jan. 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as CaCO3 (mg/l)	TOC (mg/l)	COD (mg/l)	BOD5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	8.5	-	-	-	-	-	54.9	11	-	0.6	2.29
Bear R. bl. Oneida res. [490620]	-	-	-	5.0	3	-	-	-	-	49.7	11	-	0.5	2.29
Bear R. W. Fairview, ID [490610]	0.0	9.2	8.8	7.5	15	757	452	305	359	21.6	33	2	0.6	3.20
Bear R. W. Richmond [490382]	0.0	9.4	9.4	13.0	24	768	458	305	-	43.7	17	1	0.6	4.24
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-	10.11
Bear R. bl. Cutler res. [490198]	-0.2	9.2	6.8	4.9	12	717	418	277	340	14.8	11	2	0.4	-
Bear R. near Honeyville [490170]	0.1	9.2	8.1	6.0	11	730	-	-	-	13.6	15	1	1.4	10.11
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	0.0	9.0	8.6	4.5	10	466	272	248	237	17.1	11	2	0.4	6.19
Cub R. W. Richmond [490425]	0.0	9.0	8.6	12.0	26	527	-	-	-	18.4	17	2	1.0	13.05
Logan R. ab. confl. w/L Bear R. [490504]	0.8	9.3	9.6	13.0	12	414	240	215	235	19.3	16	2	0.6	0
L. Bear R. W. Avon [490570]	0.7	9.4	10.1	2.6	6	429	254	226	236	16.0	15	1	0.4	0
L. Bear bl. Hyrum res. [490565]	1.4	9.3	9.4	1.8	4	469	-	-	-	14.3	13	1	0.6	2.29
L. Bear ab. confl. w/Logan R. [490500]	2.4	9.0	8.1	18.0	32	683	372	284	317	22.0	<10	4	2.7	32.42

02 Jan. 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	<0.1	<0.01	0.71	0.09	0.13	-	-	-	-	-	-	0.05	10
Bear R. bl. Oneida res. [490620]	<0.1	<0.01	0.65	0.06	<0.01	-	-	-	-	-	-	0.07	10
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.68	0.06	0.03	45	6	65	48	50	56	0.13	25
Bear R. W. Richmond [490382]	<0.1	0.01	0.78	0.14	0.05	50	7	64	44	57	65	0.19	30
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	0.02	0.80	0.09	0.06	41	6	70	40	47	56	0.10	10
Bear R. near Honeyville [490170]	0.1	0.01	0.83	0.21	0.07	-	-	-	-	-	-	0.12	15
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	0.1	0.02	1.23	0.08	0.05	16	3	59	22	12	15	0.28	60
Cub R. W. Richmond [490425]	0.3	0.01	1.91	0.18	0.15	-	-	-	-	-	-	0.25	60
Logan R. ab. confl. w/L Bear R. [490504]	0.1	0.01	0.38	0.06	0.01	5	1	58	22	5	15	0.07	<10
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.33	0.05	<0.01	8	1	55	24	10	13	0.09	10
L. Bear bl. Hyrum res. [490565]	0.2	0.01	0.76	0.28	0.01	-	-	-	-	-	-	0.04	<10
L. Bear ab. confl. w/Logan R. [490500]	2.3	0.13	1.20	0.46	0.46	25	5	71	34	29	45	0.12	30

05 Feb. 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	0.0	-	-	4.0	3	340	-	-	-	-	-	1	-	-
Bear R. W. Fairview, ID [490610]	0.0	8.9	8.5	4.0	8	785	-	300	379	9.5	11	1	0.4	-
Bear R. W. Richmond [490382]	0.0	8.9	9.8	6.2	11	832	500	309	327	7.7	22	1	0.4	-
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	0.2	8.5	10.3	7.0	11	789	298	306	260	38.4	15	1	0.4	-
Bear R. bl. Cutler res. [490198]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. near Honeyville [490170]	0.1	8.9	7.4	4.0	14	740	-	-	-	39.4	<10	1	0.6	-
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Richmond [490425]	0.0	8.9	9.1	24.0	65	500	-	-	-	35.4	<10	3	0.6	-
Logan R. ab. confl. w/L Bear R. [490504]	1.6	8.8	9.5	4.5	11	409	228	218	208	1.0	30	1	0.1	-
L. Bear R. W. Avon [490570]	1.4	9.1	9.9	4.5	14	420	250	226	197	13.0	13	1	0.5	-
L. Bear bl. Hyrum res. [490565]	1.2	9.1	10.2	-	<3	477	-	-	-	8.9	<10	1	0.3	-
L. Bear ab. confl. w/Logan R. [490500]	1.2	8.8	9.3	7.0	24	518	294	242	259	3.4	<10	1	0.3	-

05 Feb. 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	0.03	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.1	<0.01	0.79	0.06	0.03	49	7	62	54	52	67	0.07	20
Bear R. W. Richmond [490382]	0.1	0.02	0.89	0.07	0.04	53	7	58	44	61	73	0.10	30
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	0.1	0.02	1.21	0.05	0.03	16	3	64	23	25	15	0.07	20
Bear R. bl. Cutler res. [490198]	-	-	-	0.05	-	-	-	-	-	-	-	-	-
Bear R. near Honeyville [490170]	0.2	<0.01	0.96	0.21	0.08	-	-	-	-	-	-	0.05	15
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Richmond [490425]	0.2	<0.01	1.86	0.23	0.20	-	-	-	-	-	-	0.22	85
Logan R. ab. confl. w/L Bear R. [490504]	0.1	<0.01	0.40	0.05	0.02	5	1	52	18	6	18	1.34	<10
L. Bear R. W. Avon [490570]	0.1	<0.01	0.35	0.07	0.03	8	1	50	17	9	12	0.06	10
L. Bear bl. Hyrum res. [490565]	0.3	<0.01	0.80	0.34	0.03	-	-	-	-	-	-	0.07	10
L. Bear ab. confl. w/Logan R. [490500]	0.1	0.03	1.20	0.08	0.04	16	3	64	23	25	15	0.06	25

05 Mar. 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	1.9	9.1	8.8	8.8	17	747	432	282	305	7.9	<10	2	0.3	16.35
Bear R. W. Richmond [490382]	1.9	9.1	8.0	14.0	30	758	432	287	323	40.7	18	1	0.2	15.34
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	0.6	9.0	8.2	8.2	11	741	434	283	309	22.9	13	1	0.3	16.35
Bear R. bl. Cutler res. [490198]	0.1	9.2	7.5	5.6	7	689	398	270	347	47.3	24	2	0.7	19.10
Bear R. near Honeyville [490170]	0.0	9.3	6.4	5.2	8	685	-	265	-	27.9	11	2	0.5	11.29
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	2.7	9.1	7.3	6.2	13	432	244	219	202	29.6	25	1	0.3	14.32
Cub R. W. Richmond [490425]	3.3	8.9	9.3	10.0	22	512	-	270	-	27.3	<10	2	0.5	20.42
Logan R. ab. confl. w/L Bear R. [490504]	2.9	9.3	7.8	4.2	9	414	228	216	215	19.1	<10	2	0.1	24.49
L. Bear R. W. Avon [490570]	4.0	9.3	7.6	9.0	<3	413	236	213	211	6.9	47	3	0.1	15.34
L. Bear bl. Hyrum res. [490565]	2.0	9.5	9.1	1.0	<3	462	-	-	-	1.1	11	1	0.1	21.43
L. Bear ab. confl. w/Logan R. [490500]	4.2	9.6	5.8	17.0	31	635	362	265	285	32.9	10	7	2.8	70.51

05 Mar. 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.1	<0.01	0.64	0.13	0.07	44	7	54	41	51	62	0.16	30
Bear R. W. Richmond [490382]	0.1	<0.01	0.71	0.10	0.10	47	7	56	44	55	61	0.18	25
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	0.1	<0.01	0.84	0.09	0.05	48	7	58	40	54	62	0.12	25
Bear R. bl. Cutler res. [490198]	0.2	<0.01	0.88	0.12	0.09	39	6	71	41	45	50	0.08	20
Bear R. near Honeyville [490170]	0.3	-	-	0.31	0.06	-	-	-	-	-	-	0.09	15
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	0.1	<0.01	1.11	0.13	0.10	16	4	50	18	11	13	0.14	35
Cub R. W. Richmond [490425]	0.4	<0.01	1.85	0.24	0.19	-	-	-	-	-	-	0.18	55
Logan R. ab. confl. w/L Bear R. [490504]	0.1	<0.01	0.41	0.08	0.03	6	1	49	22	7	16	0.09	10
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.33	0.09	0.04	9	1	48	22	11	12	0.14	20
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.79	0.10	0.05	-	-	-	-	-	-	0.03	<10
L. Bear ab. confl. w/Logan R. [490500]	2.4	<0.01	3.02	0.61	0.51	24	6	59	33	28	42	0.15	30

02 Apr. 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	38.0	65	-	-	-	-	59.4	20	3	1.1	24.94
Bear R. bl. Oneida res. [490620]	-	-	-	10.0	<3	-	-	-	-	12.9	39	2	0.6	24.41
Bear R. W. Fairview, ID [490610]	-	-	-	-	-	-	-	-	-	-	-	-	-	21.76
Bear R. W. Richmond [490382]	4.4	7.8	9.1	25.0	450	747	430	249	275	9.8	11	3	0.7	20.70
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	5.0	7.9	9.0	53.0	86	729	419	257	324	4.9	<10	3	0.7	21.76
Bear R. bl. Cutler res. [490198]	5.7	7.8	8.9	33.0	58	702	408	260	288	6.2	13	3	0.8	20.70
Bear R. near Honeyville [490170]	5.7	7.9	9.0	27.0	60	718	-	-	-	5.4	19	2	0.7	20.70
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	7.4	7.8	8.1	27.0	63	397	244	178	165	3.3	14	2	0.8	72.71
Cub R. W. Richmond [490425]	-	-	-	-	-	-	-	-	-	-	-	-	-	111.19
Logan R. ab. confl. w/L Bear R. [490504]	6.2	7.8	8.8	17.0	45	410	238	205	216	29.3	19	1	0.1	18.59
L. Bear R. W. Avon [490570]	-	-	-	-	-	-	-	-	-	-	-	-	-	17.53
L. Bear bl. Hyrum res. [490565]	4.0	7.8	10.2	6.7	15	441	-	-	-	3.1	11	1	0.3	15.43
L. Bear ab. confl. w/Logan R. [490500]	4.6	7.5	7.3	31.0	85	760	464	324	380	14.4	43	10	3.4	87.26

02 Apr. 1985 cont.

Station	NH4-N (mg/l)	NO2-N (mg/l)	NO3-N (mg/l)	TP (mg/l)	PO4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	0.2	<0.01	1.35	0.17	0.07	-	-	-	-	-	-	0.39	45
Bear R. bl. Oneida res. [490620]	0.1	<0.01	0.55	0.04	0.02	-	-	-	-	-	-	0.16	35
Bear R. W. Fairview, ID [490610]	-	-	-	0.35	0.04	-	-	-	-	-	-	-	-
Bear R. W. Richmond [490382]	0.2	<0.01	1.35	0.50	0.46	51	9	55	33	59	66	1.87	250
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	0.3	<0.01	1.53	0.17	0.07	51	9	62	41	55	59	0.51	80
Bear R. bl. Cutler res. [490198]	0.5	<0.01	1.61	0.19	0.12	44	9	56	36	51	51	0.36	50
Bear R. near Honeyville [490170]	0.4	-	-	0.28	0.13	-	-	-	-	-	-	0.32	40
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	0.3	<0.01	1.92	0.23	0.19	19	5	41	15	14	13	0.42	70
Cub R. W. Richmond [490425]	-	-	-	0.82	0.29	-	-	-	-	-	-	-	-
Logan R. ab. confl. w/L Bear R. [490504]	0.1	<0.01	0.69	0.05	0.03	7	2	55	19	10	14	0.27	25
L. Bear R. W. Avon [490570]	-	-	-	-	0.07	-	-	-	-	-	-	-	-
L. Bear bl. Hyrum res. [490565]	0.1	-	-	0.2	0.03	-	-	-	-	-	-	0.12	20
L. Bear ab. confl. w/Logan R. [490500]	1.9	<0.01	5.96	0.75	0.73	30	15	69	50	33	40	0.34	80

30 Apr. 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)	NaOH-P (μg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	19.0	48	-	-	-	-	20.9	11	2	1.1	-
Bear R. bl. Oneida res. [490620]	-	-	-	9.1	16	-	-	-	-	21.6	<10	2	0.8	-
Bear R. W. Fairview, ID [490610]	12.1	8.0	11.1	28.0	97	604	336	237	258	26.2	13	2	1.1	-
Bear R. W. Richmond [490382]	13.2	8.2	9.9	38.0	120	628	368	237	262	16.6	66	2	0.9	-
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	14.2	8.1	10.7	57.0	150	600	352	203	248	25.6	<10	2	1.1	-
Bear R. bl. Cutler res. [490198]	13.5	7.9	9.7	66.0	193	556	330	224	220	22.3	<10	3	1.1	-
Bear R. near Honeyville [490170]	14.0	7.9	8.3	80.0	117	557	-	-	-	11.4	<10	4	1.1	-
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	13.0	8.2	10.1	12.0	69	302	174	161	152	3.3	<10	1	0.5	-
Cub R. W. Richmond [490425]	13.9	8.1	9.2	46.0	130	365	-	-	-	10.3	<10	2	0.7	-
Logan R. ab. confl. w/L Bear R. [490504]	9.9	8.5	10.2	18.0	85	355	198	188	171	5.9	17	1	0.4	-
L. Bear R. W. Avon [490570]	10.4	8.2	9.5	11.0	38	330	188	170	166	6.6	<10	3	3.0	-
L. Bear bl. Hyrum res. [490565]	12.7	8.1	10.6	4.5	7	360	-	-	-	5.8	<10	1	0.4	-
L. Bear ab. confl. w/Logan R. [490500]	13.0	7.9	8.5	48.0	69	615	354	275	304	13.5	10	5	1.7	-

30 Apr. 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (µg/l)
Bear R. ab. Oneida res. [490630]	<0.1	<0.01	0.58	0.07	0.01	-	-	-	-	-	-	0.26	60
Bear R. bl. Oneida res. [490620]	<0.1	<0.01	0.53	0.02	0.15	-	-	-	-	-	-	0.15	45
Bear R. W. Fairview, ID [490610]	0.1	0.19	0.67	0.06	0.01	36	6	58	28	41	42	0.31	80
Bear R. W. Richmond [490382]	<0.1	0.22	0.78	0.09	0.02	39	6	59	28	45	46	0.38	100
Bear R. bl. confl. w/Cub R. [490368]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	0.2	0.17	0.96	0.11	0.025	43	7	54	28	41	43	0.53	105
Bear R. bl. Cutler res. [490198]	0.4	0.07	0.91	0.20	0.03	31	5	52	22	36	35	0.58	105
Bear R. near Honeyville [490170]	0.1	<0.01	0.76	0.33	0.05	-	-	-	-	-	-	0.49	100
W. Side Canal [490195]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. Franklin, ID [490379]	<0.1	0.03	0.56	0.08	<0.05	5	1	43	11	4	5	0.16	35
Cub R. W. Richmond [490425]	0.1	<0.01	1.00	0.15	0.05	-	-	-	-	-	-	0.50	100
Logan R. ab. confl. w/L Bear R. [490504]	<0.1	0.03	0.32	0.03	<0.05	5	1	47	13	6	10	0.35	30
L. Bear R. W. Avon [490570]	0.1	0.06	0.26	0.03	0.01	8	2	44	14	8	7	0.17	30
L. Bear bl. Hyrum res. [490565]	0.1	<0.01	0.79	0.23	0.03	-	-	-	-	-	-	0.08	25
L. Bear ab. confl. w/Logan R. [490500]	0.9	0.01	2.25	0.33	0.31	21	5	64	35	21	41	0.18	40

Appendix C

Fecal indicator bacteria concentrations in samples taken from the Bear River and its tributaries between May 1984 and April 1985.

Indicator bacteria in samples taken from the Bear River and it's tributaries, 1984 through 1985.

Sampling Date	3 April 1984				1 May 1984				
Station	TC[1] #/100 ml	FC[2] #/100 ml	FS[3] #/100 ml	CP-T[4] MPN/100 ml	TC #/100 ml	FC #/100 ml	FS #/100 ml	CP-T MPN/100 ml	CP-S[5] MPN/100 ml
Bear R. ab. Oneida Res. [490630]	NA*	NA	NA	14	NA	NA	NA	30	50
Bear R. bl. Oneida Res. [490620]	NA	NA	NA	80	400	10	32	23	80
Bear R. W. Fairview, ID [490610]	700	8	152	30	700	0	96	NA	NA
Bear R. W. Richmond [490382]	1000	12	128	110	600	0	160	NA	NA
Bear R. bl. confl. w/Cub R. [490368]	1200	0	44	80	500	80	48	80	300
Bear R. ab. Cutler res. [490326]	1000	4	104	240	100	92	170	80	27
Bear R. bl. Cutler res. [490198]	700	4	64	80	300	88	92	240	240
Bear R. @ I-15 near Honeyville [490170]	300	8	200	27	400	20	40	240	170
W. Side Canal [490195]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cub R. W. Franklin, ID [490379]	3500	16	420	33	700	220	150	NA	NA
Cub R. W. Richmond [490425]	4200	164	840	300	2300	680	240	110	<240
Logan R. ab. Confl. w/L.Bear R. [490504]	400	0	16	17	1300	112	36	NA	NA
L. Bear R. W. Avon [490570]	400	0	56	50	2000	1	100	NA	NA
L. Bear R. Bl. Hyrum res. [490565]	500	0	0	4	1100	1	44	NA	NA
L. Bear R. abv. confl.w/Logan R. [490500]	700	0	12	23	3300	370	330	NA	NA

[1]Total coliforms/100 ml; membrane filter method.
[2]Fecal coliforms/100 ml; membrane filter method.
[3]Fecal streptococci/100 ml; membrane filter method.
[4]Total Clostridium perfringens/100 ml; most probable number (MPN) method.
[5]Clostridium perfringens spores/100 ml;MPN or membrane filter method (#)
*Not analyzed (NA)

Indicator bacteria in samples taken from the Bear River and it's tributaries, 1984 through 1985.

Sampling Date	30 May 1984				10 July 1984				
Station	TC[1] #/100 ml	FC[2] #/100 ml	FS[3] #/100 ml	CP-T[4] MPN/100 ml	TC #/100 ml	FC #/100 ml	FS #/100 ml	CP-T MPN/100 ml	CP-S[5] #/100 ml
Bear R. ab. Oneida Res. [490630]	400	20	210	30	<100	8	800	50	10
Bear R. bl. Oneida Res. [490620]	1400	240	180	50	200	280	200	27	2
Bear R. W. Fairview, ID [490610]	600	100	910	30	100	96	2100	30	3
Bear R. W. Richmond [490382]	200	60	1000	34	100	84	300	27	10
Bear R. bl. confl. w/Cub R. [490368]	1300	64	970	130	<100	64	1500	50	5
Bear R. ab. Cutler res. [490326]	700	168	1400	130	100	72	200	14	2
Bear R. bl. Cutler res. [490198]	200	12	600	170	100	160	600	70	17
Bear R. @ I-15 near Honeyville [490170]	1200	32	-	80	<100	16	500	130	7
W. Side Canal [490195]	200	12	900	170	200	220	100	110	14
Cub R. W. Franklin, ID [490379]	1100	120	880	30	<100	60	400	2	2
Cub R. W. Richmond [490425]	600	170	-	23	100	56	900	500	47
Logan R. ab. Confl. w/L.Bear R. [490504	800	132	208	13	<100	40	100	30	4
L. Bear R. W. Avon [490570]	1200	72	84	NA	100	104	500	NA	NA
L. Bear R. Bl. Hyrum res. [490565]	1400	24	160	17	<100	52	1300	11	1
L. Bear R. abv. confl.w/Logan R. [490500]	4400	96	400	30	200	80	800	240	84

[1]Total coliforms/100 ml; membrane filter method.
[2]Fecal coliforms/100 ml; membrane filter method.
[3]Fecal streptococci/100 ml; membrane filter method.
[4]Total *Clostridium perfringens*/100 ml; most probable number (MPN) method.
[5]*Clostridium perfringens* spores/100 ml;MPN or membrane filter method (#)
*Not analyzed (NA)

Indicator bacteria in samples taken from the Bear River and it's tributaries, 1984 through 1985.

Sampling Date	7 August 1984				5 September 1984			
Station	TC[1] #/100 ml	FC[2] #/100 ml	FS[3] #/100 ml	CP-S[5] #/100 ml	TC #/100 ml	FC #/100 ml	FS #/100 ml	CP-S #/100 ml
Bear R. ab. Oneida Res. [490630]	-	100	0	5	300	230	200	1
Bear R. bl. Oneida Res. [490620]	-	0	3000	3	100	28	200	1
Bear R. W. Fairview, ID [490610]	-	2200	500	3	300	240	1000	3
Bear R. W. Richmond [490382]	-	5000	700	3	1500	1080	2100	7
Bear R. bl. confl. w/Cub R. [490368]	-	4500	2800	5	100	170	1100	4
Bear R. ab. Cutler res. [490326]	-	2000	300	7	300	370	300	6
Bear R. bl. Cutler res. [490198]	-	100	600	16	800	1300	1100	4
Bear R. @ I-15 near Honeyville [490170]	-	120	1700	10	200	160	500	9
W. Side Canal [490195]	-	2000	6500	8	1800	260	800	7
Cub R. W. Franklin, ID [490379]	24	5300	100	4	800	180	1200	7
Cub R. W. Richmond [490425]	-	3000	100	43	1700	280	700	73
Logan R. ab. Confl. w/L.Bear R. [490504	-	2000	800	14	-	-	-	3
L. Bear R. W. Avon [490570]	-	2400	400	-	400	84	1900	3
L. Bear R. Bl. Hyrum res. [490565]	-	1500	900	1	200	26	1600	<1
L. Bear R. abv. confl.w/Logan R. [490500]	-	3500	3500	410	7300	900	1000	125

1Total coliforms/100 ml; membrane filter method.
2Fecal coliforms/100 ml; membrane filter method.
3Fecal streptococci/100 ml; membrane filter method.
4Total Clostridium perfringens/100 ml; most probable number (MPN) method.
5Clostridium perfringens spores/100 ml;MPN or membrane filter method (#)
*Not analyzed (NA)

Indicator bacteria in samples taken from the Bear River and it's tributaries, 1984 through 1985.

Sampling Date	2 October 1984				23 October 1984			
Station	TC[1] #/100 ml	FC[2] #/100 ml	FS[3] #/100 ml	CP-S[5] #/100 ml	TC #/100 ml	FC #/100 ml	FS #/100 ml	CP-S #/100 ml
Bear R. ab. Oneida Res. [490630]	NA	NA	NA	NA	NA	NA	NA	NA
Bear R. bl. Oneida Res. [490620]	NA	NA	NA	NA	NA	NA	NA	NA
Bear R. W. Fairview, ID [490610]	100	80	480	5	400	12	150	5
Bear R. W. Richmond [490382	250	40	1500	94	50	8	600	4
Bear R. bl. confl. w/Cub R. [490368]	NA	NA	NA	NA	20	20	160	NA
Bear R. ab. Cutler res. [490326]	210	120	330	4	200	48	300	2
Bear R. bl. Cutler res. [490198]	700	116	800	3	500	24	300	3
Bear R. @ I-15 near Honeyville [490170]	100	60	600	7	NA	NA	NA	<1
W. Side Canal [490195]	300	90	3200	13	600	50	350	11
Cub R. W. Franklin, ID [490379]	180	100	360	14	650	130	200	10
Cub R. W. Richmond [490425]	-	160	2200	94	200	8	650	21
Logan R. ab. Confl. w/L.Bear R. [490504	170	48	240	6	550	8	100	5
L. Bear R. W. Avon [490570]	140	20	140	NA	300	12	50	NA
L. Bear R. Bl. Hyrum res. [490565]	70	8	340	0	150	8	600	2
L. Bear R. abv. confl.w/Logan R. [490500]	-	330	1800	76	2000	70	150	39

[1]Total coliforms/100 ml; membrane filter method.
[2]Fecal coliforms/100 ml; membrane filter method.
[3]Fecal streptococci/100 ml; membrane filter method.
[4]Total *Clostridium perfringens*/100 ml; most probable number (MPN) method.
[5]*Clostridium perfringens* spores/100 ml;MPN or membrane filter method (#)
*Not analyzed (NA)

Indicator bacteria in samples taken from the Bear River and it's tributaries, 1984 through 1985.

Sampling Date	27 November 1984			5 March 1985		
Station	TC[1] #/100 ml	FC[2] #/100 ml	FS[3] #/100 ml	TC #/100 ml	FC #/100 ml	FS #/100 ml
Bear R. ab. Oneida Res. [490630]	NA	NA	NA	NA	NA	NA
Bear R. bl. Oneida Res. [490620]	850	36	1200	NA	NA	NA
Bear R. W. Fairview, ID [490610]	1600	5	120	65	NA	200
Bear R. W. Richmond [490382]	100	0	400	60	NA	20
Bear R. bl. confl. w/Cub R. [490368]	NA	NA	NA	NA	NA	NA
Bear R. ab. Cutler res. [490326]	NA	NA	NA	200	24	700
Bear R. bl. Cutler res. [490198]	NA	NA	NA	30	4	50
Bear R. @ I-15 near Honeyville [490170]	NA	NA	NA	300	8	1400
W. Side Canal [490195]	600	30	7900	NA	NA	NA
Cub R. W. Franklin, ID [490379]	100	<1	200	120	4	200
Cub R. W. Richmond [490425]	100	<1	100	200	64	500
Logan R. ab. Confl. w/L.Bear R. [490504	600	28	3600	120	16	200
L. Bear R. W. Avon [490570]	600	32	8200	80	8	200
L. Bear R. Bl. Hyrum res. [490565]	200	24	800	NA	NA	NA
L. Bear R. abv. confl.w/Logan R. [490500]	-	-	-	2800	1800	5100

[1]Total coliforms/100 ml; membrane filter method.
[2]Fecal coliforms/100 ml; membrane filter method.
[3]Fecal streptococci/100 ml; membrane filter method.
[4]Total *Clostridium perfringens*/100 ml; most probable number (MPN) method.
[5]*Clostridium perfringens* spores/100 ml;MPN or membrane filter method (#)
*Not analyzed (NA)

Indicator bacteria in samples taken from the Bear River and it's tributaries, 1984 through 1985.

Sampling Date	2 April 1985		
Station	TC[1] #/100 ml	FC[2] #/100 ml	FS[3] #/100 ml
Bear R. ab. Oneida Res. [490630]	180	60	4100
Bear R. bl. Oneida Res. [490620]	20	0	200
Bear R. W. Fairview, ID [490610]	NA	NA	NA
Bear R. W. Richmond [490382]	100	0	2400
Bear R. bl. confl. w/Cub R. [490368]	NA	NA	NA
Bear R. ab. Cutler res. [490326]	200	30	2200
Bear R. bl. Cutler res. [490198]	400	0	800
Bear R. @ I-15 near Honeyville [490170]	0	20	1400
W. Side Canal [490195]	NA	NA	NA
Cub R. W. Franklin, ID [490379]	<100	0	1700
Cub R. W. Richmond [490425]	NA	NA	NA
Logan R. ab. Confl. w/L.Bear R. [490504	220	90	200
L. Bear R. W. Avon [490570]	NA	NA	NA
L. Bear R. Bl. Hyrum res. [490565]	400	50	500
L. Bear R. abv. confl.w/Logan R. [490500]	<100	0	3400

[1]Total coliforms/100 ml; membrane filter method.
[2]Fecal coliforms/100 ml; membrane filter method.
[3]Fecal streptococci/100 ml; membrane filter method.
[4]Total *Clostridium perfringens*/100 ml; most probable number (MPN) method.
[5]*Clostridium perfringens* spores/100 ml;MPN or membrane filter method (#)
*Not analyzed (NA)

Appendix D

Meteorological data and temperature model coefficients used in modeling the proposed Amalga Reservoir. The year 1979 represents a low flow year and 1980 a high flow year. Data were taken from the weather station at Richmond.

Meteorological Coefficients and Data (Richmond-Amalga) 1979.

					Coefficients						
Month	# of Days	Solar	Sunrise	Sunset	Evap. A	Evap. B	Shade	Extin.	Beta A	AB 2	Pressure
April	30	5370	5.5	18.5	0.0	0.10E-08	0.1	0.711	0.53	101	870
May	31	6650	5.5	18.5	0.0	0.10E-08	0.1	0.911	0.53	101	870
June	30	7420	5.0	19.0	0.0	0.10E-08	0.1	0.911	0.53	101	872
July	31	7980	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	872
Aug.	31	6860	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	871
Sept.	30	5530	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	873
Oct.	31	3870	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	873

			Data - Three Hour Intervals (2:00 - 23:00)						
	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
April	Temperature (°C)	3.83	3.28	6.06	10.50	12.17	12.72	7.72	5.50
	Sky Cover (Tenths)	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7
	Windspeed (m/s)	4.11	2.79	2.49	7.04	6.60	6.31	1.32	1.76
	Relative Humidity (%)	53.0	53.0	45.0	31.0	26.0	22.0	38.0	48.0
May	Temperature (°C)	7.39	6.28	12.39	16.83	18.50	18.50	12.94	9.06
	Sky Cover (Tenths)	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	Windspeed (m/s)	1.76	1.32	2.79	8.07	8.22	6.31	1.03	0.15
	Relative Humidty (%)	46.0	50.0	34.0	19.0	14.0	12.0	27.0	41.0
June	Temperature (°C)	11.94	10.28	17.50	22.50	24.72	25.83	19.17	19.72
	Sky Cover (Tenths)	0.3	0.4	0.2	0.3	0.3	0.3	0.3	0.3
	Windspeed (m/s)	2.05	1.03	3.67	6.01	6.75	7.63	0.73	0.15
	Relative Humidty (%)	37.0	40.0	25.0	13.0	10.0	8.0	23.0	31.0
July	Temperature (°C)	15.39	14.39	20.39	25.94	28.72	28.72	22.61	17.61
	Sky Cover (Tenths)	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.4
	Windspeed (m/s)	0.59	0.00	2.64	4.69	5.87	4.69	0.00	0.00
	Relative Humidty (%)	26.0	30.0	17.0	5.0	1.0	0.0	10.0	8.0

Meteorological Coefficients and Data (Richmond-Amalga) 1979 (Continued).

	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
Aug.	Temperature (°C)	16.33	15.22	19.67	25.22	28.00	27.44	21.33	18.00
	Sky Cover (Tenths)	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
	Windspeed (m/s)	0.15	0.15	1.32	4.99	5.72	4.40	0.00	1.03
	Relative Humidty (%)	30.0	34.0	21.0	6.0	0.0	1.0	17.0	25.0
Sept.	Temperature (°C)	13.39	12.28	16.17	23.94	27.50	26.72	16.17	12.28
	Sky Cover (Tenths)	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
	Windspeed (m/s)	2.49	1.03	1.32	3.08	6.45	4.11	0.00	0.44
	Relative Humidty (%)	28.0	32.0	22.0	4.0	0.0	0.0	20.0	25.0
Oct.	Temperature (°C)	6.50	5.94	8.72	15.39	17.61	16.50	9.83	7.61
	Sky Cover (Tenths)	0.4	0.4	0.5	0.6	0.6	0.5	0.5	0.4
	Windspeed (m/s)	2.05	2.49	3.08	2.20	4.40	2.26	0.00	2.20
	Relative Humidty (%)	43.0	45.0	37.0	14.0	11.0	14.0	38.0	42.0

Meteorological Coefficients and Data (Richmond-Amalga) 1980.

Month	# of Days	Solar	Sunrise	Sunset	Coefficients Evap. A	Evap. B	Shade	Extin.	Beta A	AB 2	Pressure
April	30	5370	5.5	18.5	0.0	0.10E-08	0.1	0.711	0.53	101	868
May	31	6650	5.5	18.5	0.0	0.10E-08	0.1	0.911	0.53	101	870
June	30	7420	5.0	19.0	0.0	0.10E-08	0.1	0.911	0.53	101	869
July	31	7980	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	871
Aug.	31	6860	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	874
Sept.	30	5530	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	869
Oct.	31	3870	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	874

	Parameter	2:00	Data - Three Hour Intervals (2:00 - 23:00) 5:00	8:00	11:00	14:00	17:00	20:00	23:00
April	Temperature (°C)	6.67	5.56	7.78	11.67	13.33	12.22	8.89	7.78
	Sky Cover (Tenths)	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.6
	Windspeed (m/s)	2.93	2.20	4.11	3.96	7.48	6.75	1.17	2.20
	Relative Humidity (%)	46.0	51.0	43.0	30.0	27.0	30.0	41.0	45.0
May	Temperature (°C)	7.78	6.67	10.56	14.44	16.11	16.67	12.22	8.89
	Sky Cover (Tenths)	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5
	Windspeed (m/s)	2.35	2.79	3.37	4.25	8.22	6.16	0.00	2.05
	Relative Humidty (%)	43.0	46.0	33.0	21.0	17.0	16.0	33.0	39.0
June	Temperature (°C)	12.78	11.11	15.56	19.44	21.67	21.67	17.22	15.00
	Sky Cover (Tenths)	0.7	0.5	0.5	0.5	0.4	0.5	0.6	0.6
	Windspeed (m/s)	1.03	1.03	2.79	4.11	5.87	6.01	0.00	1.32
	Relative Humidty (%)	36.0	41.0	27.0	13.0	17.0	17.0	21.0	31.0
July	Temperature (°C)	17.67	16.00	20.44	25.44	27.67	27.11	22.67	18.78
	Sky Cover (Tenths)	0.5	0.5	0.4	0.3	0.3	0.4	0.4	0.4
	Windspeed (m/s)	0.88	0.29	0.15	4.25	5.13	5.43	0.00	0.44
	Relative Humidty (%)	24.0	28.0	18.0	4.0	0.0	1.0	12.0	21.0

Meteorological Coefficients and Data (Richmond-Amalga) 1980 (Continued).

	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
Aug.	Temperature (°C)	16.22	15.11	18.44	26.89	26.22	25.11	20.11	17.33
	Sky Cover (Tenths)	0.5	0.5	0.4	0.4	0.4	0.5	0.6	0.6
	Windspeed (m/s)	1.32	0.29	2.49	3.81	4.84	3.81	0.00	1.47
	Relative Humidty (%)	31.0	35.0	26.0	11.0	3.0	5.0	24.0	28.0
Sept.	Temperature (°C)	13.44	12.33	15.11	20.11	22.89	21.78	16.22	14.00
	Sky Cover (Tenths)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Windspeed (m/s)	1.47	1.17	2.05	1.76	6.16	4.84	0.00	2.35
	Relative Humidty (%)	30.0	35.0	26.0	7.0	1.0	2.0	24.0	27.0
Oct.	Temperature (°C)	5.11	4.56	6.22	12.89	14.56	13.44	7.89	6.22
	Sky Cover (Tenths)	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.4
	Windspeed (m/s)	1.76	1.91	1.76	2.49	5.43	4.40	0.00	0.88
	Relative Humidty (%)	42.0	41.0	38.0	14.0	11.0	14.0	37.0	43.0

Appendix E

Meteorological data and temperature model coefficients used in modeling the proposed Honeyville Reservoir. The year 1979 represents a low flow year and 1980 a high flow year. Data were taken from the weather station at Corrine.

Meteorological Coefficients and Data (Corrine-Honeyville) 1979.

Month	# of Days	Solar	Sunrise	Sunset	Evap. A	Evap. B	Shade	Extin.	Beta A	AB 2	Pressure
					Coefficients						
April	30	5370	5.5	18.5	0.0	0.10E-08	0.1	0.711	0.53	101	870
May	31	6770	5.5	18.5	0.0	0.10E-08	0.1	0.911	0.53	101	870
June	30	7150	5.0	19.0	0.0	0.10E-08	0.1	0.911	0.53	101	872
July	31	7590	5.5	18.5	0.0	0.10E-08	0.1	!.!!0	0.53	101	872
Aug.	31	6330	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	871
Sept.	30	5490	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	873
Oct.	31	3430	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	873

Data - Three Hour Intervals (2:00 - 23:00)

	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
April	Temperature (°C)	4.94	3.83	7.17	11.61	13.28	13.83	8.83	6.61
	Sky Cover (Tenths)	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7
	Windspeed (m/s)	4.69	3.37	2.93	7.48	7.18	6.89	1.91	2.35
	Relative Humidity (%)	53.0	53.0	45.0	31.0	26.0	22.0	38.0	48.0
May	Temperature (°C)	9.06	7.94	14.06	18.5	20.17	20.17	14.61	10.72
	Sky Cover (Tenths)	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	Windspeed (m/s)	2.35	1.91	3.37	8.66	8.80	6.89	1.61	0.73
	Relative Humidty (%)	43.0	47.0	31.0	16.0	11.0	9.0	24.0	38.0
June	Temperature (°C)	13.06	11.39	18.61	23.61	25.83	26.94	20.28	15.28
	Sky Cover (Tenths)	0.3	0.4	0.2	0.3	0.3	0.3	0.3	0.3
	Windspeed (m/s)	2.05	1.03	3.67	6.01	6.75	7.63	0.73	0.15
	Relative Humidty (%)	41.0	44.0	29.0	17.0	14.0	12.0	27.0	35.0
July	Temperature (°C)	16.50	15.39	21.50	27.06	29.83	29.83	23.72	18.72
	Sky Cover (Tenths)	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.4
	Windspeed (m/s)	1.47	0.88	4.25	5.57	6.75	5.57	0.00	0.73
	Relative Humidty (%)	31.0	35.0	22.0	10.0	6.0	5.0	15.0	23.0

Meteorological Coefficients and Data (Corrine-Honeyville) 1979 (Continued).

	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
Aug.	Temperature (°C)	16.33	15.22	19.67	25.22	28.00	27.44	21.33	18.00
	Sky Cover (Tenths)	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
	Windspeed (m/s)	0.88	0.88	2.05	5.72	6.45	5.13	0.00	1.76
	Relative Humidty (%)	34.0	38.0	25.0	10.0	4.0	5.0	21.0	29.0
Sept.	Temperature (°C)	12.39	11.28	15.17	22.94	26.28	25.72	16.83	13.50
	Sky Cover (Tenths)	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
	Windspeed (m/s)	2.93	1.47	1.76	3.52	6.89	4.55	0.00	0.88
	Relative Humidty (%)	29.0	33.0	23.0	5.0	0.0	0.0	21.0	26.0
Oct.	Temperature (°C)	5.94	5.39	8.17	14.83	17.06	15.94	9.28	7.06
	Sky Cover (Tenths)	0.4	0.4	0.5	0.6	0.6	0.5	0.5	0.4
	Windspeed (m/s)	2.35	2.79	3.37	2.49	4.69	2.93	0.00	2.49
	Relative Humidty (%)	53.0	57.0	49.0	26.0	23.0	26.0	50.0	60.0

Meteorological Coefficients and Data (Corrine-Honeyville) 1980.

Month	# of Days	Solar	Sunrise	Sunset	Coefficients Evap. A	Evap. B	Shade	Extin.	Beta A	AB 2	Pressure
April	30	5370	5.5	18.5	0.0	0.10E-08	0.1	0.711	0.53	101	868
May	31	6770	5.5	18.5	0.0	0.10E-08	0.1	0.911	0.53	101	870
June	30	7150	5.0	19.0	0.0	0.10E-08	0.1	0.911	0.53	101	869
July	31	7590	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	871
Aug.	31	6330	5.5	18.5	0.0	0.10E-08	0.1	1.110	0.53	101	874
Sept.	30	5490	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	869
Oct.	31	3430	6.5	17.5	0.0	0.10E-08	0.1	1.110	0.53	101	874

			Data - Three Hour Intervals (2:00 - 23:00)						
	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
April	Temperature (°C)	7.61	6.50	8.72	12.6	14.27	13.16	9.83	8.72
	Sky Cover (Tenths)	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.6
	Windspeed (m/s)	3.52	2.78	4.69	4.69	8.06	7.33	1.76	2.78
	Relative Humidity (%)	46.0	51.0	43.0	30.0	27.0	30.0	41.0	45.0
May	Temperature (°C)	9.44	8.33	12.22	16.11	17.78	18.33	13.89	10.56
	Sky Cover (Tenths)	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.5
	Windspeed (m/s)	2.93	3.37	3.96	4.84	8.80	6.75	0.15	2.64
	Relative Humidty (%)	40.0	43.0	3.0	18.0	14.0	13.0	26.0	2.0
June	Temperature (°C)	14.06	12.94	17.39	21.28	23.50	23.50	19.06	16.28
	Sky Cover (Tenths)	0.7	0.5	0.5	0.5	0.4	0.5	0.6	0.6
	Windspeed (m/s)	1.61	1.61	3.37	4.69	6.45	6.60	0.44	1.91
	Relative Humidty (%)	40.0	45.0	31.0	17.0	11.0	11.0	25.0	19.0
July	Temperature (°C)	19.17	17.50	21.94	26.94	29.17	28.61	24.17	20.28
	Sky Cover (Tenths)	0.5	0.5	0.4	0.3	0.3	0.4	0.4	0.4
	Windspeed (m/s)	1.76	1.17	1.03	5.13	6.01	6.31	0.29	1.32
	Relative Humidty (%)	29.0	33.0	23.0	9.0	4.0	6.0	17.0	26.0

Meteorological Coefficients and Data (Corrine-Honeyville) 1980 (Continued).

	Parameter	2:00	5:00	8:00	11:00	14:00	17:00	20:00	23:00
Aug.	Temperature (°C)	16.83	15.72	19.06	23.50	26.83	25.72	20.72	17.94
	Sky Cover (Tenths)	0.5	0.5	0.4	0.4	0.4	0.5	0.6	0.6
	Windspeed (m/s)	2.05	1.03	3.23	4.55	5.57	4.55	0.44	2.20
	Relative Humidty (%)	35.0	39.0	30.0	13.0	7.0	9.0	28.0	38.0
Sept.	Temperature (°C)	13.22	12.11	14.89	19.89	22.67	21.56	16.0	13.78
	Sky Cover (Tenths)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Windspeed (m/s)	1.91	1.61	2.49	2.20	6.60	5.28	0.15	2.79
	Relative Humidty (%)	31.0	36.0	27.0	8.0	2.0	3.0	25.0	28.0
Oct.	Temperature (°C)	5.17	4.61	6.28	12.94	14.61	13.50	7.94	6.28
	Sky Cover (Tenths)	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.4
	Windspeed (m/s)	2.05	2.20	2.05	2.79	5.72	4.69	0.00	1.17
	Relative Humidty (%)	54.0	53.0	50.0	26.0	23.0	26.0	36.0	29.0